MINNEAPOLIS, MINN. Oct. 19, 1899

To Library, Cornell University, N.Y.

I have the pleasure of presenting, in the name of the board of regents of the University of Minnesota, this copy of the volume 4 of the *final report on the geological and natural history survey of Minnesota.*

N. H. WINCHELL,

State Geologist.

Ack 23/12/99

Date Due

NOV 2 [illegible]			

UNIVERSITY OF MINNESOTA.

A REPORT

ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA;
MADE IN PURSUANCE OF AN ACT OF THE LEGISLATURE
OF THE STATE, APPROVED MARCH 1,
1872.

PUBLISHED BY AUTHORITY OF THE STATE.

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VOLUME IV.

LETTER OF N. H. WINCHELL, STATE GEOLOGIST.

UNIVERSITY OF MINNESOTA,
MINNEAPOLIS, December 31, 1898.

Hon. J. S. Pillsbury, President of the Board of Regents:

MY DEAR SIR: I have the honor to tender herewith for publication the fourth volume of the final report on the Geological and Natural History Survey of the state. In pursuance of the plan adopted when the survey was begun, this volume covers the areal geology of the northern one-third portion, thus completing the survey on the plan pursued. The final report is to embrace one more volume and an atlas.

Permit me to thank you for your continued interest in the survey, and for numerous courtesies received in the course of its prosecution.

Respectfully submitted,

N. H. WINCHELL,
State Geologist.

LETTER OF J. S. PILLSBURY, PRESIDENT OF THE BOARD OF REGENTS.

UNIVERSITY OF MINNESOTA,
MINNEAPOLIS, MINN., January 2, 1899.

Prof. N. H. Winchell, City:

MY DEAR SIR: In acknowledging receipt of your favor, tendering for publication the fourth volume of the final report of the geological survey, completing the areal geology of the state, I wish to express the thanks of the regents, and of the people of the state, for the persistence and thoroughness with which you have carried on this survey. For its unity of plan and administration, as well as for its difficulties and its final success, there has been no state survey like it.

I shall use my best endeavor to have this volume published promptly.

Very respectfully,

JOHN S. PILLSBURY,
President of the Board of Regents of the University of Minnesota.


GEOLOGICAL
AND
NATURAL HISTORY SURVEY
OF
MINNESOTA.
N H WINCHELL, STATE GEOLOGIST
Scale, 42 miles to an inch.
KEY TO THE
GEOLOGICAL PLATES.

THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

N. H. WINCHELL, STATE GEOLOGIST.

1896—1898.

THE

GEOLOGY OF MINNESOTA.

VOL. IV OF THE FINAL REPORT.

BY N. H. WINCHELL.

ASSISTED BY ULYSSES S. GRANT, JAMES E. TODD, WARREN UPHAM
AND HORACE V. WINCHELL.

SUBMITTED JANUARY 1, 1899, AND PUBLISHED UNDER DIRECTION OF THE
BOARD OF REGENTS OF THE UNIVERSITY.

ILLUSTRATED BY THIRTY-ONE COLORED GEOLOGICAL PLATES

FORTY-EIGHT PLATES OF PHOTOGRAPHIC VIEWS

AND 114 FIGURES.

ST. PAUL, MINN.
THE PIONEER PRESS CO., PRINTERS.
1899.

TABLE OF CONTENTS.

LIST OF PLATES AND THEIR ORDER.

PREFACE.

According to the plan pursued from the commencement of the survey, the state has been examined progressively, and the counties mapped and described from south to north. This volume covers the area of about the northern one-third part of the state. By the key-plate, which is the frontispiece, the reader will observe the location of the different areas or counties to which the special chapters are devoted.

This volume has to do very largely with the area of the crystalline rocks, *i. e.*, with the Taconic and the Archean. In the north central and northwestern portions of the state, however, the drift monopolizes attention, since the underlying rocks are nearly unknown. The questions that are discussed and the conclusions that are expressed in this volume respecting the indurated rocks are based largely on details that are to be included in volume v. In that volume will be found also a summary statement of the systematic geology of these ancient rocks as it has been worked out by the examinations carried on by the Minnesota survey.

This volume, therefore, completes the areal geology of the state. By that it is not intended to convey the idea that the geology of the state is completed. The parties of the survey have, however, gone over the whole state, and have noted the geological boundaries, and have herewith expressed what seemed to them, from their often cursory review, the structural relations which the rocks and the drift features present to the geological observer. There remains, however, much to be done—indeed, more than has already been done—to warrant the statement that the geology of the state is even satisfactorily worked out. Considering the time devoted to the northern part of the state, the available means and the smallness of the number of men that have been employed, and the size and difficulties of the region, the results may be considered satisfactory. The subjects are far-reaching, complex and numerous. It is therefore more in the sense that this form of publication of the results of the survey is now extended so as to include the whole state's area in its scope, that the survey is completed. While some of the geological questions that this field examination has started are to have further discussion in volume v, there are many that cannot be considered. This is owing to the exigency of the demand to "complete" the survey according to the geographical plan of progress which has been followed.

The reader, therefore, will not be surprised to find frequent statements that, in this direction or in that line of examination, it is impossible to give final statements.

The results are frequently tentative or only apparent, and, while our descriptions, so far as they go, may be taken as expressions of fact, and our interpretations as in harmony with the facts in our possession, there may be other important facts which, not included in our field of observation, will in the future place different interpretations on those which we have attempted to group systematically under certain broad principles.

There having been a great and a difficult area to be examined, and several geologists to put interpretations on a lot of new facts, the reader will not be surprised, again, to learn that the observers do not always agree as to the manner of interpretation of the structural facts that they have observed. This remark is true, not only of those who have studied the drift of the central and northern part of the area here mapped, but especially of some of the multifarious questions that pertain to the oldest rocks. Every geologist, however, has been allowed perfect freedom in the expression of his views, and is to be held responsible only for his own. In this stage of investigation, the geology of the state would not be furthered by dogmatism, nor by authoritative restrictions on the assistants. However true that is of certain fields of geology in which the stratigraphy and many of its attendant problems of organic and physical evolution have been solved, and only need to be extended over some new areas, it is manifestly and emphatically true of any area involving the crystalline rocks of the bottom of the geological series. Here the geologist is deprived of his usual guides and guys, and finds himself floundering in a muddy sea of innumerable conflicting currents. Everyone has to depend chiefly upon himself, for there is scarcely a common current in which he can float easily and safely. He can simply look out for himself, under the guidance of the facts of his own field of vision.

It is only recently that the Archean has been subjected to any classification in advance of the old duality of Huronian-Laurentian. The results given in this volume, therefore, so far as they appertain to the Archean, have been wrought out almost entirely in a new field, from a set of new facts, which in their variety and number probably exceed those ever before assembled under a single classification.

The Archean. The following brief outline will aid the reader to apprehend the relations and the significance of the various facts given in detail in the body of the volume. It begins with the bottom of the geological scale.

1. The Keewatin. This is divisible into Lower and Upper, separated by a conglomerate at the base of the Upper.

The Lower Keewatin contains two parts, both consisting of greenstone. The lower part is considered the oldest rock in the state. It is mainly an igneous rock, a massive greenstone, and is supposed to represent the cooled original crust of the earth. The other part is fragmental and chemical, and embraces the jaspilytes and

iron ores of the Vermilion range. The upper portion of the Lower Keewatin is frequently agglomeratic, and occasionally a greenstone conglomerate separates it from the massive lower portion. In the midst of the upper portion of the Lower Keewatin appears a vast mass of quartz-porphyry. On theoretical grounds, this is tentatively supposed to represent an alkaline mud produced by precipitation from the Archean ocean, the porphyritic crystals of quartz and orthoclase having been formed from supersaturation in a hot solution. The jaspilytes sometimes embracing iron ore, are a product of similar precipitation. This quartz-porphyry is the earliest appearance of acid rock. It is not known to cut the bottom greenstones, but it is abundantly distributed as debris in the upper part of the Lower Keewatin. All later quartz-porphyries, appearing as dikes in the Upper Keewatin, are supposed to be offshoots from this old mass, either by infolding and dike-like protrusions, or from plastic conditions brought about by regional metamorphism.

The Upper Keewatin has as its base the Ogishke conglomerate, which is the eastern representative of the Stuntz conglomerate of Vermilion lake. Above this conglomerate are graywackes, argillytes and (in one instance) jaspilyte. The Upper Keewatin is compactly folded in with the Lower Keewatin, and in many instances the two series stand vertical alongside of each other; indeed, in nearly all parts of the state, where known, these rocks are found standing on edge. The basal conglomerate of the Upper Keewatin is sometimes so destitute of acid elements that it appears like the upper part of the Lower Keewatin, especially wherever a fine debris from an older greenstone was abundant. In the same way, whenever it lies on granite, its lowest portions are difficult to distinguish from the granite.

The source of the green element of the fragmental greenstones, both of the Lower and of the Upper Keewatin, was also largely from Archean volcanoes, and these were concerned in promoting the copious siliceous and alkaline precipitations mentioned.

2. *Metamorphism.* There is a large series of clastic gneisses produced by the recrystallization of the Keewatin strata. When these old strata were basic they are supposed to have given origin to the dark gneisses; but from the far more abundant acid clastics were formed by metamorphism the greater mass of acid clastic gneisses. These gneisses grade into mica schists which present similar extremes.

3. *Igneous rocks.* Dynamic and thermal effects, through moisture, resulted in the fusion of the acid clastics, giving rise to granites, syenytes, diorytes, etc., with varying acidity. The same forces caused the fusion of the basic rocks of the Keewatin, producing diabase, gabbro, orthoclase gabbro, syenytes, etc., with their varying basicity, there being a gradation from the most acid of the former group, through all degrees of acidity to the most ultra basic of the latter group. In the main,

the larger original masses, whether acid or basic, retain their predominant types in their descendants, and their descendants occupy in the main the parental places in their geographic distribution. Later dikes of diabase, as well as of granite, are from the same original masses, taking their places in later formations under stress of dynamic force acting on their deep-seated portions.

The Taconic. This is the time equivalent of the Lower Cambrian and is separated from the foregoing by another marked non-conformity. It is divided into Animikie (at the bottom) and Potsdam. These are both intimately associated with igneous rocks. The former carries the Mesabi iron ores and the latter the copper deposits of lake Superior. The former is sometimes nearly horizontal, but sometimes dips as much as 45° from horizontal. The latter is usually less tilted than the former. The two are separated by a non-conformity. The conglomerate and quartzyte at the base of the Potsdam (locally named Puckwunge conglomerate) is widespread in Minnesota and Wisconsin and has received also the names Sioux quartzyte, New Ulm quartzyte, Baraboo quartzyte and Barron quartzyte. It graduates upward into sandstones, which are well known along the St. Louis river and on the south side of lake Superior, and these in turn graduate into the St. Croix sandstones and the dolomytes of the Mississippi valley. The conglomerate and the lower sandstones are accompanied by cotemporary basic lavas.

The Animikie, so far as known, has no cotemporary lava flows in Minnesota, but is intersected by sills and dikes of diabase—offshoots from the great gabbro mass which originated and took its structural positions at the close of the Animikie and before the Puckwunge conglomerate.

The eruptives of the Keweenawan are divided, according to their date, into Cabotian and Manitou, the former antedating the Puckwunge conglomerate, and the latter accompanying and following it.

As in the Archean, so in the Taconic, the igneous rocks, both acid and basic, originated from metamorphism and finally the fusion of older (usually clastic) rocks, the diabase being traced directly into gabbro, and the gabbro, through muscovadyte, into greenstone; and the granites being traceable to quartz-porphyry, and that rock the result of aqueo-igneous fusion of clastics, in some cases plainly those of the Animikie.

There are granites of at least three determined relative dates, two in the Archean and one in the Taconic.

There are also diabase dikes of at least three determined relative dates, one in the Archean and two in the Taconic.

There are quartz-porphyry dikes of at least three dates, one cutting the upper part of the Lower Keewatin, one cutting the Upper Keewatin, and one cutting parts of the Taconic.

The granite dikes are referable to fused or plastic portions of the acid fragmentals of older date.

The diabase dikes are believed to have originated from the lowest greenstones, or as apophyses from the gabbro, itself a secondary condition of the greenstones.

The quartz-porphyry dikes sprung, under similar forces, from the great quartz-porphyry of the Lower Keewatin, or from later clastics.

The divisions, and probably the subdivisions, of the Archean, were determined by epochal earth-movements, which not only caused the upheaval and metamorphism of all pre-existing rocks along certain belts of greatest stress, but also gave origin and relative date to the igneous rocks. These great movements are marked also by the accumulation of the coarser or conglomeratic portions of the clastic strata, these coarser clastic strata following immediately after the cessation of the general disturbance, or in some cases being cotemporary with it.

The divisions of the Taconic are due to the recurrence of similar disturbances in Lower Cambrian time; products of such metamorphism being the gabbro with its attendants (diabase dikes and surface lavas) when the rocks affected were sufficiently basic, and constituting the "red rock" series (granites, quartz-porphyries and acid lavas) when the rocks concerned were acid.

The successive belts which witnessed the maximum disturbance have, in northeastern Minnesota, a rude parallelism extending northeast and southwest, and from the earliest to the youngest approach more and more to the basin of lake Superior, and appear to have outlined the northwestern confines of that basin in some of the earliest stages of geologic history. While these characteristic belts can be easily recognized only in the northeastern part of the state, it is believed, from the scant data that we have, that they extend entirely across the state in the same direction, and that they could be traced continuously were it not for the heavy covering of drift. Therefore the nomenclature, and the geologic history which is so plain in the northern part of the state, are reasonably extended southwestwardly as far as to South Dakota.

Methods of topography. As the accompanying geological plates are marked by topographical contour lines, it will be well to remind the reader that they are not based on the same simple methods as were employed in the southern and western counties. In the most of the state are numerous railroads, and railroad and other surveys. These data have been used as bases from which, by rapid travel and aneroid readings, the contours of the surrounding country have been sketched in and corrected. In the northeastern part of the state such data are nearly always wanting. At the same time there is no portion of the state in which there is concentrated a more diversified topography, nor any in which the intimate dependence of topography on

geology is so evident. The topography, therefore, is, in a marked manner, the interpreter and the guide to the geology. It was obvious at once that some method must be devised for expressing this relationship, and therefore for first expressing the salient contours of the topography.

In order to do this with the available means of the survey, each party sent out in the season of 1893 was furnished with a copy of uniform instructions for making topographic records, of which the following is a transcript. Each party carried the necessary apparatus for making the contour lines on the township plats, which they had in duplicate, one set being for geology and one for topography:

DIRECTIONS FOR FIELD WORK FOR TOPOGRAPHICAL MAPS OF THE MESABI IRON RANGE AND OF OTHER PARTS OF NORTHERN MINNESOTA.

Contour lines of township maps. Starting from known elevations, of which a list is appended, the aneroid barometer is to be used, first, for the determination of altitudes of *primary points of reference.* Each township will have its own series of such primary points, marked (●) and lettered A, B, C, etc., among which will be included all the camping places of the party. The locations of these points, and their altitudes as barometrically determined, are to be recorded on the township plats. The altitudes of the principal lakes are also to be determined and noted on the plats, and all the large lakes are to be used with the foregoing as primary planes of reference. These altitudes upon each township plat are to be harmonized together and brought as nearly as possible to be consistent with each other by reading the barometer whenever a journey is made between such primary stations and lakes, or from any of them to primary stations and lakes in adjoining townships or to points whose hights are known.

It is intended that each party will keep a continuous computation of the hight of its primary stations with reference to the sea level, independent of the fluctuations of the barometer caused by changing meteorologic conditions. For this computation, the altitude of each new primary station will be obtained by barometric comparison with stations of known hight or with former primary stations, when as little time as practicable is spent in passing from one station to the other. In such determinations of new stations, several readings (at least three) of the barometer at intervals of a half hour are to be taken at the station of already determined altitude just previous to leaving it; and immediately on arrival at the new station several readings (at least three) with the same intervals of time are likewise to be made, all these being recorded in the field-book. By inspection of these series it will be seen whether the barometric pressure was probably changing, and in which direction, while the journey between these stations was being made, and this correction is to be applied in obtaining the altitude of the new station.

From the points and planes of reference the hights and locations of the principal hills and ridges of the district will be determined similarly by the barometer and noted as *secondary stations* marked * on the township plats; and from each of these elevations the form of the adjoining country is to be sketched on the plats in contour lines with vertical intervals of fifty feet, reckoned from sea level through the known data before referred to, the calculated hights of the successive contour lines being noted on the plats. In this work altitudes at distances of a half mile to one mile, or farther, away from the observer may be ascertained approximately by sighting with the Locke's level from the points where the hight is known by the barometer. This sketching is to be done by pencil at the high secondary stations where the barometric altitude is read.

When the primary hights relied on for the secondary stations and sketching are subsequently found to require changes and adjustments which affect the hights of the contours sketched, the changes needed are to be made also by pencil, by noting at each secondary station the estimated number of feet, with + or — sign, by which the previously assigned altitudes of the contour lines in its vicinity are to be changed for agreement with the more accurate barometric determinations and for consistency with each other and with adjoining township plats. At the primary and secondary stations and on the areas of lakes the plats must give references to the pages of the field-books where their original determinations and all later adjustments are stated in detail.

All the areas of the townships assigned to your party, namely: (specification of the area assigned to the party) are to be covered with contour lines drawn as above described, from which the map plates of these areas will be compiled for the final report. Graphic records of your observations of the contour must be given fully by these lines on your several township plats.

Notes in field-books. While the whole area of each of the designated townships is to be carefully contoured on the plats as indicated in these instructions, especial attention is to be given to the chief belt of outcrop of the iron-bearing formations, which is on the northern line of the slates at their junction with granite or quartzyte. Along this belt and upon a width of a half mile or more to each side from it, the survey is to be done with exceptional thoroughness and fullness of detail. Here continuous observations are to be taken along each north and south line of sections and their subdivisions, and brief descriptive notes of their altitudes, slopes and ravines

are to be recorded or sketched in the field-books, previous to the usual sketch mapping of the contour lines of hills and ridges.

For the purpose of the final mapping, all the barometric readings at the primary reference points or lakes, and at every secondary station from which sketching is done, are to be recorded carefully in your field-books with definite statements of the locations of these points, lakes and stations, as to the section, township and range, and the situation in the section. In all cases the aneroid barometer is to be read both in inches and in feet, as barometer 29.132=1,710 feet, while it is laid or held in horizontal position and after a slight jarring that the needle may freely come to rest. The times of all barometric readings are to be entered with them in the field-books, whereby these field records will be conveniently corrected by comparison with the continuous records of a mercurial barometer read regularly during each day at some station of known hight on the Mesabi Iron range.

An example of the notation in the field-book for an aneroid reading, with its location and time, and its computed hight, is therefore as follows: Barometer 29.132=1,710 feet—Primary station B, S. E. ¼ sec. 1, T. 58–17—June 15, 10:30 a. m.,—Computed hight, 1,565 feet. More exact description of the location of this station, with reference to the sides and corners of this quarter section, is to be given also, unless it has been previously determined and so described on a foregoing page, and its position is to be indicated on the plat thus, ● B.

[*Sample page.*]

BAROMETRIC RECORDS FOR THE MONTH OF JUNE.

DATE AND RECORD.

Stations	John Smith, Observer.							
●	3 7:30 A	3 9:30 A	3 12 M	3 6 P	3 6:30 P	3 7 P		
A	28.435 2375	28.405 2402	28.355 2450	28.365 2440	28.375 2431	28.385 2422		
*	3 8:00 A	3 9 A						
a	28.335 2468	28.325 2477						
*	3 11:00 A	3 11:30 A						
b	28.010 2782	28.010 2782						
*	3 3 P							
c	28.175 2622							
*	3 4 P							
d	28.065 2728							
●	3 7:30 P	4 7 A	4 7:30 A	4 5 P	4 5:30 P	5 6 A		
B	28.375 2431	28.445 2366	28.440 2370	28.600 2212	28.610 2202	28.625 2190		
*	4 9 A	4 9:30 A			*	5 9:30 A	5 10:30	
d	28.105 2688	28.105 2688			i	28.200 2597	28.200 2597	
*	4 10:30 A	4 12 M			*	5 1:30 P	*	5 4.00 P
e	28.000 2790	28.015 2778			j	28.445 2366	k	28.445 2366
*	4 1 P							
f	28.200 2597							
*	4 2:30 P	4 3 P	4 3:30 P	5 7 A				
g	28.300 2504	28.310 2495	28.325 2484					
*	5 7:30 A	5 8 A						
h	28.350 2455	28.360 2445						

The readings of the mercurial barometer and of the temperature at its station will be recorded at the even hours and half hours throughout the day. For comparison therewith the aneroid barometer should be read likewise at even hours and half hours. For these readings the aneroid is to be placed on the ground.

The field-books are also to contain brief notes of the conditions of the weather at morning, noon, and night and whenever noteworthy changes are observed, as to clear or partly or wholly cloudy sky; calmness or direction of the wind, and whether it is slight, moderate or strong; the duration and character of rains, and especially of showers, noting their time of beginning and end; and the character of the temperature, as cool, mild, warm, or hot, and the time of any sudden changes of temperature, as during or after showers. Note particularly the oncoming of thunder storms, as their isobars move across the country from west to east and will serve, in the final compilation, for correcting the aneroid readings of the several parties.

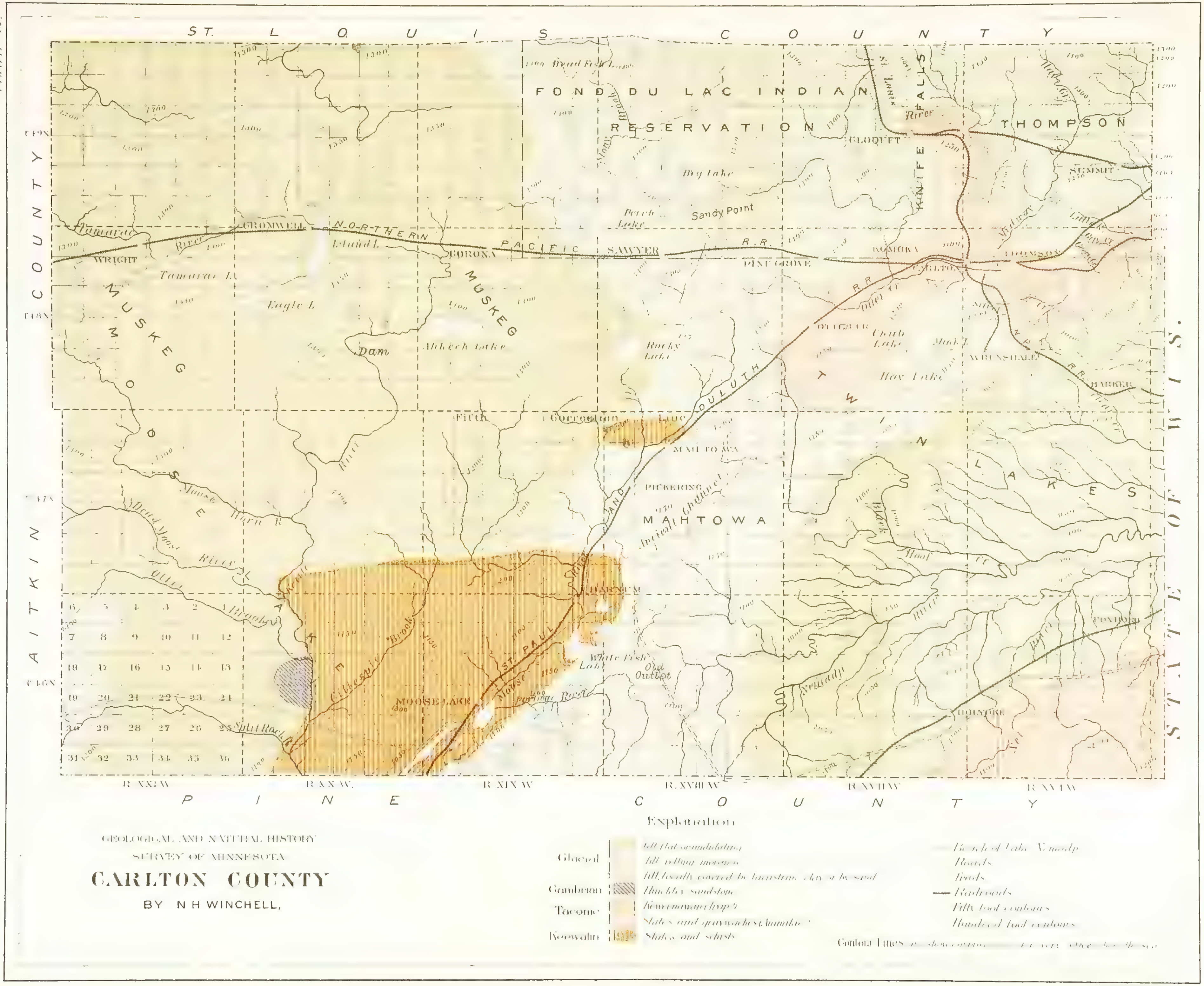
The stations are designated thus: ● Primary station. *=Secondary station. A=A. M. P=P. M. M=Noon. Capitals A, B, C, to Z=Primary stations. Lower case a, b, c, to z=Secondary stations.

Supplementary. If it be found impracticable to keep a continuous record and calculation of the elevation in feet above the sea, thus drawing the contour lines where they will permanently remain, the topographer may contour the separate townships from assumed primary stations. Such assumed points should have numerous aneroid readings recorded in the field notes for correction by the mercurial barometer, and they should be, if possible, either the highest or lowest points in the township, or the surface of some large lake. The contour lines drawn at intervals of fifty feet from such data will receive their correction when the records are all compared.

Accompanying these instructions was a list of all known elevations within the area to be contoured. The mercurial barometer by which the aneroids were corrected was read each half hour at the station where the Duluth and Iron Range railroad crosses the Mesabi Iron range, and by it all the aneroids were set.

This plan was carried out with varying accuracy and fullness by the different parties; and at the same time a line of spirit levels was run northward from Grand Marais to the international boundary, calculated to furnish positive hypsometric data in one of the most important as well as complicated portions of the state. From this line many short branch lines were run to lakes and to hills. The data gathered by this examination, which went on in connection with geological notes, and the readings of the stationary mercurial barometer, were submitted to Mr. Upham, and by him were drawn finally the most of the contours represented on the special geological plates of the Mesabi Iron range. In the region of Akeley and Gunflint lakes, however, the contours are essentially those of Dr. Grant, and those of the Hibbing, Virginia and Mountain Iron plates are as constructed by Mr. Spurr. Those of Carlton county are by Mr. Ayres.

Date of some of the chapters. The field work of the survey was done in some parts of the area included in this volume several years ago, and there is some discrepancy between the maps and the descriptions and the present state of development. This is particularly true of the special maps of the western part of the Mesabi Iron range, where the larger part of the developments which have astonished all engaged in the iron industry have taken place since the survey was made. There has been no opportunity to make more recent examinations, such as the circumstances would warrant. In other cases there have been some changes in the boundaries of the counties in the northwestern part of the state since the reports were written and the drawings of the maps were executed. It has not been possible to recast the reports nor to make the county boundaries conform to these changes. N. H. W.


ST. LOUIS COUNTY
AITKIN COUNTY
PINE COUNTY
STATE OF WIS.
FOND DU LAC INDIAN RESERVATION
THOMPSON
KNIFE FALLS
MUSKEG
MOOSE LAKE
MAHTOWA
TWIN LAKES
CROMWELL
WRIGHT
CORONA
SAWYER
PINE GROVE
KOMOKA
CLOQUET
CARLTON
THOMSON
SUMMIT
BARNUM
PICKERING
MAHTOWA
WRENSHALL
BARKER
HOLYOKE
FOXBORO
NORTHERN PACIFIC R.R.
ST. PAUL AND DULUTH R.R.
Sandy Point
Big Lake
Perch Lake
Rocky Lake
Chub Lake
Hay Lake
Eagle L.
Tamarac L.
Island L.
Dam
Moose Horn R.
Dead Moose River
Otter Brook
Gillespie Brook
Moose Lake
White Fish Lake
Old Outlet
Ancient Channel
Split Rock R.
Portage Brook
Fifth Correction Line
R. XXI W.
R. XX W.
R. XIX W.
R. XVIII W.
R. XVII W.
R. XVI W.
T. 49 N.
T. 48 N.
T. 47 N.
T. 46 N.
Explanation
Glacial
Till flat or undulating
Till rolling morainic
Till locally covered by lacustrine clay or by sand
Cambrian
Hinckley sandstone
Taconic
Keweenawan (trap?)
Slates and graywackes (Animikie)
Keewatin
Slates and schists
Beach of Lake Nemadji
Roads
Trails
Railroads
Fifty foot contours
Hundred foot contours
GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA
CARLTON COUNTY
BY N H WINCHELL.

CHAPTER I.

THE GEOLOGY OF CARLTON COUNTY.*

By N. H. WINCHELL.

Situation and area. This county is situated on the western rim of the lake Superior valley. Its waters drain both ways—eastwardly and southwestwardly. Its area is 867.19 square miles, of which 9.47 square miles are water. Its form is that of a rectangle east and west, bordering on the state of Wisconsin south of the St. Louis river.

SURFACE FEATURES.

Natural drainage. The St. Louis river crosses the northeastern corner of the county, but it drains an insignificant amount of the surface. About one-fifth of the county, the southeastern part, is drained by the upper waters of the Nemadji river, while the larger part of the county contributes to the Mississippi through the Prairie and Kettle rivers. In the central and northwestern portions of the county are several fine lakes, and in the latter region these lakes are accompanied by extensive marginal swamps.

Topography. In general the surface varies from flat to rolling and hilly. That portion of the county which is drained to the valley of lake Superior is quite rough, the rivers having excavated deep and sharp cañon-like valleys in the drift which would have otherwise an even upper surface. This is more particularly true of the area drained by the Nemadji, for the St. Louis river, so far as it is within this county, is yet mainly outside the ancient valley that was submerged by lake Superior during the accumulation of the drift, and hence the drift maintains a rough contour that is more characteristic of the drift-covered latitudes. The most of the county is rather smooth, similar to the flat drift-covered counties in the western part of the state, the flatness being broken only by the drainage courses. The only noteworthy

*Carlton county was in part examined in 1879, and many rock samples were collected, as recorded in the 10th annual report, pp. 9-34 (Nos. 443-510). Further examination was made in September, 1893, in company with Mr. H. B. Ayers, and later with Mr. J. E. Spurr. In June, 1894, Mr. Ayers again assisted, and finally, in July, 1894, and May, 1897, several of the interesting and important rock outcrops were again reviewed in company with Mr. Ayers and Dr. U. S. Grant. The topographical work expressed on the plate of the county (No. 56) is essentially that of Mr. Ayers, who traveled over the whole county with an aneroid barometer for the purpose. The petrographic geology of Carlton county will be found in detail in volume 5 in connection with the rocks listed from this county.

exceptions to the original flat or undulating contour besides those mentioned above are found in a belt near the centre of the county, extending northeast and southwest about eight miles in width which is morainic, and an area in the extreme northeastern corner of the county. There is another small area in the southwestern corner of the county which is also rough with original morainic deposits. There are three important features in the topography of this county, aside from the usual general monotony, *viz.:* (1) The St. Louis river valley. (2) The Nemadji plains and cañons, and, (3) The old outlets of lake Superior.

(1). The valley of the St. Louis river. In the main this river is bounded on either side by high drift-walls composed of the morainic drift of the region. These walls are distant from the river proper from half a mile to two miles, and they are undulating or rounded, and cut by numerous drainage courses that cross them, and are reduced by the superficial wash that is incident to atmospheric exposure since the deposition of the material. From Cloquet downward the river runs on the rock, and continues thus to near Fond du Lac. Near the eastern boundary of the county the surface drift features change from the morainic to lacustrine, assuming thus the characters seen in the Nemadji valley. The immediate valley eastward from the eastern boundary of the county is therefore of more recent excavation than that portion which is excavated in the morainic drift. The rocks are nowhere much worn by the river. There are but few narrow gorges, but frequent cascades or falls. The gorge through which the river runs under the railroad bridge between Carlton and Thomson may be mentioned. Here the excavation is greater than at any other place, but it is not all due to the action of the river. There are many dikes that cut the formation in that neighborhood, and the rock of these dikes is rotted more than the rock of the slates and quartzyte. One such, about the width of the river, runs north and south through the country exactly where this gorge is. The bridge therefore spans both dike and river. Everywhere these dikes are rotted below the surface of the other rocks, and they are usually marked by trenches in the older rocks, formed by their more rapid removal. It is probable that the occurrence of such a trench determined the location of the river at that point when it had to seek a passage on the retirement of lake Nemadji from the vicinity. The river here is concentrated within a narrow channel, and its erosive action, after it began, has been by that means accelerated.

(2). The Nemadji valley. Is a lacustrine plain, underlain by stratified clay and by fine sand. The area of this clay extends northward nearly or quite to the St. Louis valley. The brick made at Wrenshall, four miles southeast from Carlton, are from this laminated lacustrine clay. The surface in this lacustrine area is nearly flat, but slopes gently toward the Nemadji proper, which runs northeast. The

Nemadji valley is thus the synclinal which expresses the most westward extension of the great valley of lake Superior. Its western border is markedly distinct by reason of the abrupt change that takes place in the surface contours on passing from the lacustrine clay to the glacial drift proper. This is true throughout its extent in Carlton county. Its southern limit is nearly coincident with the southern boundary of Carlton county, passing into Wisconsin. Throughout this plain the streams have cut into the upper surface of the drift and formed sharp and deep trenches, but they do not, so far as known, certainly come into contact with the bed rock at any point in Carlton county.

(3). The old outlets of lake Superior. Otter creek, which joins the St. Louis at Carlton, flows there in an old channel between drift bluffs that are quite marked, and are separated from each other from one to two miles. This old channel is distinctly traceable for some distance toward the southwest, approximately in the direction of the St. Paul and Duluth railroad, but somewhat to the south of the track. It passes through Otter Creek and Mahtowa (townships) and near Barnum it unites with the valley of the Moose river, and thence is tributary to the Kettle river. This old channel runs through morainic drift. In section 12, Mahtowa, it has a blind connection with the Blackhoof valley, but the Blackhoof river itself is now running at a lower level, and the water in the old channel (a small stream) in order to reach it, flows in the opposite direction from what it pursued when the old channel was full. This old channel is probably the oldest and highest of the westward outlets of lake Superior, and was formed through the terminal moraine which bounded the Superior ice lobe in glacial times.

There is another ancient channel equally marked, in township 46, range 18. This passes across the divide between Moose river and Nemadji, and is specially visible in sections 16 and 17, where there is now no water except in spring time. Toward the west this channel is occupied by a tributary of Moose river, and toward the east by a tributary of the Nemadji, which immediately commences to meander across the plain toward lake Superior. This channel is lower than the other, and probably was an outlet of lake Superior when it covered the Nemadji valley and was forming the lacustrine clay which covers it. Its highest point is 1,070 feet above tide, or 468 feet above lake Superior. The upper channel is about 1,125 feet above tide, or 523 feet above lake Superior.

Elevations, St. Paul & Duluth Railroad.

	Miles from St. Paul.	Feet above the sea.
Moose Lake station,	108.8	1,063
Summit, natural surface,	111.8	1,115
Summit, grade,	112.0	1,108
Barnum,	113.4	1,100

	Miles from St. Paul.	Feet above the sea.
Moose Horn river (water, 1,091), grade,	113.5	1,101
Cut (16 feet deep), grade,	114.1	1,110
Cut (21 feet deep), grade,	117.1	1,135
Mahtowa,	119.5	1,147
Blackhoof summit (natural surface and grade the same; highest point on this railroad),	120.7	1,170
Otter creek,	125.2	1,150
Carlton (N. P. Junction),	131.5	1,083
St. Louis river, Dalles bridge (bed, 992; low and high water, 997-1,020), grade,	132.5	1,044
Thomson,	133.0	1,055
Big Gulch (bottom of culvert, 981), grade,	135.1	1,095
Summit siding (cut here has maximum depth of 24 feet),	135.9-136.1	1,115
KNIFE FALLS BRANCH.		
Carlton,	131.5	1,083
St. Louis river (crest of Knife falls, 1,167, having a perpendicular fall of 8 feet; high water on crest of falls, 1,172), grade,	136.4	1,180
St. Louis river, at head of the rapids above the falls, ordinary stage, about,	137.3	1,175

Northern Pacific Railroad.

	Miles from Duluth.	Feet above the sea.
Thomson,	21.7	1,032
Carlton,		1,083
St. Louis river, Dalles bridge (bed, 992; low and high water, 997-1,020), grade,	22.0	1,044
Otter creek, bed,	26.4	1,128
Pine Grove,	28.3	1,237
Sawyer,	33.5	1,317
Corona,	39.0	1,303
Kettle river, bed,	41.1	1,287
Summit, natural surface,	44.0	1,331
Cornwell, at Island lake,	45.0	1,306
Tamarack river (bed, 1,287), grade,	50.7	1,301
Wright,	51.0	1,309
Summit of grade, 1½ miles southeast of Carlton, in a rock cut, 18 feet deep,		1,098
Wrenshall,		1,044
Barker,		953

Duluth & Winnipeg Railroad (Great Northern).

	Miles from Duluth.	Feet above the sea.
Summit station,		
Midway river (bed, 1,153), grade,	17.7	1,182
Summit (cutting 14 feet), grade,	18.8	1,202
St. Louis river (bed, 1,116 feet), grade,	20.9	1,173
Cloquet,	22.7	1,191
Nagonab,	30.7	1,214

Elevations Determined by the U. S. Engineer Corps.

The following elevations were published by the Mississippi River Commission, in 1892, having been determined in 1891:

NOTE. -In this list A. P. B. M. indicates a precise benchmark which is set with special care so as to be practically permanent.

A. T. B. M. indicates a temporary benchmark whose elevation is as well determined as the P. B. M. but which is not regarded as specially permanent.

To reduce to mean gulf level at Biloxi, Miss., subtract 21.26 feet (preliminary value) from the elevations here given.

U. S. P. B. M. 4 is top of copper bolt, in vitrified clay slab in ground, and surmounted by iron pipe. It is 49 feet south of the St. P. & D. railway track, and 6,890 feet east of the depot at Thomson, Carlton county, Minn. It is 298 feet west of a cattle guard, and 2.5 feet north of the right of way south fence. Elevation, 1,090.664 feet.

U. S. P. B. M. 4-A is top of iron cap on top of pipe over P. B. M. 4, described above. Elevation 1,094.640 feet.

U. S. P. B. M. 5 is cross-cut on top of windowsill of the Carlton county courthouse at Carlton, Minn. It is

in the first window north of the tower and on the western side of the building. The benchmark is marked thus: U. S. + B. M. Elevation, 1,109.847 feet.

T. B. M. 39 is spike in root of pine tree 3 feet in diameter, on eastern side of public road leading south from Carlton, Minn. It is about 2,950 feet north of the junction of the public road with the old military road leading from Superior to St. Paul. Elevation, 1,131.314 feet.

U. S. P. B. M. 6 is top of copper bolt in vitrified clay slab in ground, and surmounted by iron pipe. It is 1 foot southward from the southern fence of the Superior and St. Paul military road and on land of Michael O'Donnell, in Carlton county, Minn. It is 371 feet eastward from the northwest corner of section 1, township 47, range 17, and is 190 feet northward from O'Donnell's house, and is about 6 miles southward from the town of Carlton. Elevation, 1,133.562 feet.

U. S. P. B. M. 6-A is top of iron cap on top of pipe over P. B. M. 6, described above. Elevation, 1,137.545 feet.

U. S. P. B. M. 7 is top of copper bolt in vitrified clay slab in ground, and surmounted by iron pipe. It is about 100 feet northward from the military road and 500 feet westward from the bridge over Blackhoof river, and 8.5 miles eastward from Barnum in Carlton county, Minn. There are two Norway pine trees blazed respectively 79 feet northward and 62 feet northeastward from the benchmark. Elevation, 1,111.167 feet.

U. S. P. B. M. 7-A is top of iron cap on top of pipe over P. B. M. 7, described above. Elevation, 1,115.165 feet.

T. B. M. 55 is spike in root of pine tree 3 feet in diameter, west of military road, about 6,140 feet southward from farm house. The benchmark is on top of a hill where the road turns southward, and is 3.4 miles southwest from Blackhoof bridge, in Carlton county, Minn. Elevation, 1,219,141 feet.

U. S. P. B. M. 8 is top of copper bolt in vitrified clay slab in ground, and surmounted by iron pipe. It is 59 feet northwestward from the military road and 193 feet northward from the junction of the military road with public road leading to Barnum. The benchmark is 3.9 miles east of Barnum, in Carlton county, Minn. Elevation, 1,185.778 feet.

U. S. P. B. M. 8-A is top of iron cap on top of pipe over P. B. M. 8, described above. Elevation, 1,189.748 feet.

U. S. P. B. M. 9 is top of copper bolt in vitrified clay slab in ground, and surmounted by iron pipe. It is in the southeast corner of section 36, and is 17 feet northward from the township corner marking townships 46 and 47, ranges 18 and 19, and being the northwest corner of township 46, range 18, in Carlton county, Minn. The township corner is marked by an iron bolt driven about 3 feet in the ground and is in the public road. The benchmark is about 1 mile east of Barnum depot. Elevation, 1,201.867 feet.

U. S. P. B. M. 9-A is top of iron cap on top of pipe over P. B. M. 9, described above. Elevation, 1,205.880 feet.

T. B. M. 59 is railroad spike in root of pine tree, 103.5 feet eastward from the threshold of the railway depot at Barnum, Carlton county, Minn. Elevation, 1,117.932 feet.

T. B. M. 62 is railroad spike in root of poplar tree, 8 feet east of fence, 58 feet east of St. P. & D. railway track, 705 feet south of public road and railroad crossing, and about 3 miles south of Barnum, Carlton county, Minn. Elevation, 1,104.353 feet.

U. S. P. B. M. 10 is top of copper bolt in vitrified clay slab in ground, and surmounted by iron pipe. It is 20 feet 8 inches from the southeast corner of L. L. Sargeant's dwelling house, in Moose Lake village, Carlton county, Minn. It is 145 feet eastward from the St. P. & D. railway track, and 282 feet eastward from the railroad depot, and 525 feet eastward from a warehouse under which is the northwest corner of section 21, township 46, range 19. Elevation, 1,080.028 feet.

U. S. P. B. M. 10-A is top of iron cap on top of pipe over P. B. M. 10, described above. Elevation, 1,084.019 feet.

The highest land in the county is in the northeast, on the east side of the St. Louis river, where the contours of 1,400 feet make a short entry south of the northern county line, one knob in section 2, township 49, range 17, being 1,450 feet high. This is due, so far as can be seen outwardly, to morainic accumulations which extend farther into St. Louis county, but it is also probable that the gabbro range which abuts on the St. Louis valley farther east, has an initial influence in the greater elevation of the rock surface as well as in the locus of the morainic deposits. From this altitude the general surface descends rather rapidly to the valley of the St. Louis river, and still more rapidly along the St. Louis valley eastward from Thomson, and at the exit of the river from the county its surface is lower than 650 feet.

Soil and Timber. The county presents great diversity of soil. The western and northwestern parts are prevailingly flat, and frequently swampy, and extensive

muskegs occur, which will become tillable only by an extensive system of artificial drainage. The eastern half of the county is much better drained, but it likewise has more stony and even rocky land that can never be made productive farming land. The Nemadji valley, while flat and clayey, and very muddy at certain seasons, yet is well drained by reason of the numerous streams that carry the surface waters rapidly into the main stream, and thence into lake Superior. Below the superficial lacustrine clay is a great thickness of till which occasionally rises through the clay to the surface. This underlying till emerges from beneath the clay all about the rim of the Nemadji basin and constitutes the rolling surface that bounds the valley.

The timber is equally diversified. About the swamps and on the sandy plains jack pine *(Pinus banksiana)* and spruce, characteristic of the region, are scattered sparingly, mingled in the drier patches with poplar and white birch, and in the more rolling and more fertile tracts with white pine, elm, oak, and the various deciduous species that have been enumerated in reports on other counties.

Hemlock. In connection with the timber trees of this county, an important exception should be noted to the general statement published in volume I. of this report,* to the effect that hemlock (*Tsuga canadensis*) is not known in the state. It is found sparingly in Carlton county, viz.: It formerly grew on the south side of Moose lake, between Moose lake and the old military road. According to Mr. Wm. Oliver, nine trees once grew there, but curiosity and vandalism have destroyed nearly all of them; on the bank of Kettle river west of Moose lake; near Howell (east of Thomson), between Howell and the St. Louis river, on section 10, township 48, range 16, near the centre of the section, in a little ravine.

In connection with this subject it is best to mention here other localities, although not in Carlton county, at which hemlock has been authentically reported as indigenous to the state, viz.: On the Duluth and Winnipeg railroad, on the line between sections 20 and 21, beyond Catlin, township 51, range 19. Quite a number of large trees are found here. According to Mr. R. G. Robinson, Pine City, there is a grove of hemlock intermixed with other woods, of more than six hundred acres, in sections 21 and 28, township 50, range 19, on the St. Louis river. Some of the trees are not less than 2½ feet in diameter, on the stump. According to the same authority there are six trees near the town line between townships 42 and 43, range 19, about eight miles east of Miller station (St. Paul and Duluth railroad). A sample from this place was to be seen (in 1885) in the office of the land department of the St. Paul and Duluth railroad. It is well known that eastward from the Minnesota boundary hemlock is quite common along the Penokee iron range.

GEOLOGICAL STRUCTURE.

There are several very important features in the geology of Carlton county, and there are also some unsettled questions as to the age of some of the rocks. The slates and other rocks at Carlton and Thomson, extending to Cloquet on the north and to Barnum and Moose Lake on the south, will here be considered as belonging to the same formation and date, and they will not be distinguished structurally from the rocks that appear west from Mahtowa, and between Mahtowa and Otter Creek. The possible separation of these slaty rocks into two series, and their age, will be found discussed in the report on the Carlton plate (plate 87).

This slaty and greenstone series, which is sometimes rather composed of graywackes and dark quartzytes, extends generally under the county as a base-

* Vol. i, p. 139.

ment, more or less broken by abrupt changes of dip and by faulting, and two later formations are, at different places, non-conformable upon it. There are to be considered, hence, the following three formations, not mentioning the drift, in descending order:

1. White sandstones, varying to red.
2. Conglomerate varying to light colored grit.
3. The slaty formation.

The Thomson slates. These slates outcrop in the St. Louis valley from near the eastern border of the county (sec. 2, T. 48, R. 16) to Cloquet, the water running over them almost constantly in cascades and rapids. In this part of the county they also spread northward and southward, being visible in low ridges north and east from Thomson, at Carlton, and cut by the Northern Pacific railroad a few miles southeastward from Carlton. Similar rocks appear at several points along the line of the St. Paul and Duluth railroad, viz., between Carlton and Otter Creek; at two miles west from Otter Creek, at Barnum and at Moose Lake. A ridge of high land appears westward from Mahtowa, caused primarily by a range of similar rock ridges which strike eastward so as to be crossed by the St. Paul and Duluth railroad about on the town line between township 48, ranges 17 and 18.

Some micaceous and rather soft and somewhat greenish schists are exposed to view along the Kettle river near the mouth of Gillespie brook and of Splitrock river in township 46, range 20 west, and northward. These are often considerably rotted, but at the mouth of Otter brook, section 16, township 46, range 20, they are firm, with quartz and pyrite, the latter mineral having been supposed to be auriferous and mined slightly for gold a few years ago.

These slaty rocks are so nearly alike that they can easily be placed in the same formation, but there is more metamorphic action apparent in the western and southern portions of the county, although the strata in the northeastern part of the county were more nearly adjacent to the great eruptive centre of the Keweenawan which also sent numerous apophyses into them. Hence it is a reasonable hypothesis that the Animikie is represented by the beds in the immediate valley of the St. Louis, from the falls at Cloquet to the foot of the lowest falls, and extending southwestward to near Otter Creek station; but that the rest of these slates are in an older formation, viz., the same that at Tower lies non-conformably on the greenstones and iron ores. The drift is so abundant that it has not been possible to find any line or boundary separating them, and it must be left to the future to establish or refute this hypothetical distinction.

Detailed descriptions, St. Louis valley.

In ascending the St. Louis valley the slate formation is first encountered a short distance above the coarse quartzose conglomerate that appears on the left bank in sections 1 and 2, township 48, range 16. Following up the conglomerate exposure, as it rises, the observer sees that it lies on a decomposing schist or slate, filling the original inequalities in its upper surface. The slates here stand nearly perpendicular as the weather separates the cleavage planes, and they strike east and west, as at Thomson, but the sedimentary bedding dips about 4° toward the southwest.

The slates make a series of falls and rapids commencing S. E. ¼ section 10, township 48, range 16, where, on the left bank, are several veins or folia of white quartz parallel with the slates, some of which are 4 to 6 inches thick. Some of the sedimentary beds of the formation here are coarse and hard, having no slatiness, but a thickness of two or three feet, but as a general rule the formation is distinctly slaty.

The cause of the lower falls is an igneous dike which crosses the river near the brink, hardening the layers of the formation. The falls cross the river stragglingly, about east and west in conformity with the strike of the formation, and descend about 22 feet in the distance of about six rods, but the water is rapidly descending in other short cascades for a quarter of a mile above the falls. Also below the falls it continues as a rapid to the foot of the islands, descending about 15 feet more. The dip, which is taken to be the general incline of the heavy beds toward the southeast, is 63°, but there is a multiplicity of folia, joints and seams, and sedimentary planes, that all confuse the question of dip.

The dike that here crosses the river channel has a marked effect on the slates, hardening and coloring them, and this is the effect, to a greater or less degree, of all the similar dikes that cut this rock in Carlton county. This dike runs north-northeast and is at least 20 feet thick. The slates are more durable than the dike, and owing to the basaltic structure that is superimposed on them, and the fineness of the dike at the contact with them, it is not easy to distinguish between the two rocks in the field. Above the falls are other similar dikes, but narrower, and the rock stands up roughly in the channel in the form of islands. At the large rock island east of the upper end of island No. 5 (the islands being numbered upstream) the dip of the formation is 27° southeast.

Just above island No. 6, in section 10, occurs the wildest and most tumultuous portion of the river, where it comes nearly along the strike of the slate. The descent here, in about a quarter of a mile, must be about 40 feet. There is no regular fall, but a rushing and foaming torrent, dashing from side to side of the channel, cut and parted by the jagged protrusions of the highly dipping slate which, by its variations of hardness forms troughs that alternate with sharp and angular ridges. The dip of the slate, which sometimes rises in the middle of the river 12 or 18 feet, and is very conspicuously disposed, varies from 30° to 48° to the south and south-southeast. The former dip is to the south and the latter to the south-southeast, the slaty cleavage being nearly perpendicular all the time. The grand bedding is in thicknesses of 15 to 24 inches, but there is also a thinner bedding which is in layers of a few inches, and probably the heavier beds would show a finer bedding under favorable weathering.

At the mouth of a little creek that comes from the north, S. W. ¼ section 10, township 48, range 16, is a fine-grained dike about 30 feet wide, and another occurs N. E. ¼ S. E. ¼ section 9, township 48, range 16, 8 feet wide, running north. Two others, one 30 feet wide, and the other about 6, are seen a short distance above the last. This is on S. E. ¼ section 9; and at 5 rods higher up is still another.

At the island on S. E. ¼ section 9 the river is very rough, as it separates and plunges among the rocks. The strike of the slate is nearly in the direction of the river. The island consists of a knob of hardened slate, and the beds that have their strike on each side of it stand up in the channel like inverted plows and cause the water to take a twirling course, first on one side for a few feet or a few rods, and then leaping over, like the turf on a coulter, on the other side, where it finds a trough from which it escapes in the same way at a lower level. This takes place on each side of this island, but is particularly interesting near the head of the island on the north side. Below the island in the main channel it then repeats this operation as it makes its way through other troughs. Generally the whole river is divided into several such troughs, but in a few places it is all embraced in one rapid chute about 25 feet in width, along the side of which there is a boiling return current upstream as the central current plunges and foams downward. Above this for half or three-quarters of a mile the river is more tame, but still constantly rapid, and impassable even for canoes, with frequent ridges of slate along shore and in the channel.

Another fall amounting to 22 feet occurs near the centre of section 8, the river passing directly across the slate from the northwest, the slate striking east and west, and the bedding dipping 33½° toward the south-southwest, swinging round to the south-southeast, and being then in a dip of 39° to 43°. This highest dip is seen at the narrows where the water crosses the strike of the heavy beds. At these falls the rock appears less slaty than usual, though occasional similar layers of more siliceous and arenaceous rock occur mingled with the slates at points lower down the dalles. These beds might be called quartzyte, though they are dark, and sometimes become finer and slaty.

The strike of the slate hills in sections 9 to 4, township 48, range 16, is east, 10° north, and the dip is from 46½° to 60° toward the south, the cleavage running almost east and west.

There is an interesting exhibition of the influence of the rocky structure on the course of the river at the railroad bridge over the St. Louis at Thomson. The river here is running in the course of a dike about 25 feet wide. This rock being more jointed, and at the same time more easily rotted and removed, has given

origin to the gorge through which the river passes under the bridge. The walls on either side being of hardened quartzitic slate are much more durable. This dike is visible in the bluff facing the bridge downstream, but it is nearly hid by its own tumbling debris, while the slates stand up firm from 60 to 70 feet above the river. The dike has a direction north-northeast, but is some crooked, and also separates, under or near the bridge, into two parts, uniting again so as to enclose an island (in high water) on which a pier of the footbridge rests. At half a mile northeast is another large dike, 60 feet wide, which comes to the river between Thomson and the railroad bridge. This runs at an angle of 46° with the strike of the slate and quartzyte hills, but it is much more easily destroyed than they.

A coarsely fragmental bed forming a feldspathic quartzyte or fine conglomerate, visibly 11 feet thick, can be seen near the old site of Miller's mill, north of Thomson about a quarter of a mile. This is hard and firm, gray and dark gray within, but weathers nearly white from the feldspathic ingredient and from the abundant quartz.

Near the highway bridge over the St. Louis is a large isolated nodule or lenticular mass of white quartz, standing conformably with the slates and rising above them on all sides. This is only an exaggerated instance of the quartz lenses that occur in smaller amount at many places in these slates. (Plate A.) Near the top this deposit is nearly 10 feet thick, north and south, but it runs but little distance downward. At the river bank, which intersects it at nearly right angles, it can be seen to run out almost entirely about 12 feet below the top, by branching and losing itself in the seams of the slate. One large root, however, runs below the water with a width of nearly 2 feet, and also another of 6 inches, but the greater part of it pinches out within 10 feet of the top. The quartz is milky white, and mainly massive, but sometimes shows a splintery cleavage in the direction of the slates. It is jointed, and disintegrates by falling out in blocks which are distributed down the river. Veins like this in this formation probably contributed formerly to the formation of the quartzose conglomerate which lies non-conformably on the slate in sections 1 and 2, township 48, range 16. In this quartz appears a little galenite, pyrite and siderite, and doubtfully a little blende. Its occurrence and its geologic relations are quite similar or identical with the many quartz veins found in the Animikie in the Thunder Bay district. The ridge along which this quartz vein is visible is charged with pyrite, some of the cubes being in a coarse member of the slate, and sometimes more than three-quarters of an inch across. It is likely that a lightly mineralized belt runs east and west across the river at this place, developed at a fracture and fault plane. The most important mineral accumulations would be likely to exist in conjunction with the north and south dikes.

At Carlton and between there and the railroad bridge over the St. Louis are numerous dikes of dark diabase. In the most westerly of these the labradorite feldspar appears porphyritically in the mass, which is not common in these dikes. They all run nearly north and south. Where they cut through the slate ridges they form trenches by reason of their more rapid decay. The average dip of the slate formation in the S. W. ¼ section 6, township 48, range 16, is 57° to the south, 5° east.

The river has its most rapid descent below the railroad crossing at Thomson. It is filled with rapids and falls all the way to the county line. There are four spots in particular where there are valuable water powers available in short distances. First in section 10, township 48, range 16, where the river, in a short space, is divided into various channels by six islands that occur between its banks. Three of these islands are above the fall, and three are below, but there is also a considerable fall above island No. 3 (numbering from below) extending to near the head of island No. 6. This whole fall is 55 feet. The existence of the islands and the widening of the river, as well as the extent through which the fall is carried, before it reaches rather quiet water again, are favorable for the improvement of this power and for its utilization. But a short distance above the head of island No. 6 is the second fall, where the river is narrow, but has the rock formation of the country in conspicuous strike along each bank, confining the water like artificial dikes within troughs which run somewhat obliquely across the course of the river, and rising in knobs and rough islands (with constant dip toward the southeast) in the midst of the river itself, sometimes 18 or 20 feet. This condition of the river extends from near the head of island No. 6 to the dike which is near the mouth of the creek that crosses the railroad on the N. W. ¼ section 10; and the fall here, which may be called cascade No. 2, amounts to 65 feet. There is then a gradual ascent of 25 feet among the rocks to the foot of the fall at island No. 7, and of 25 feet more in getting round the island itself, where the river is divided and beautified by the disposition of the slate ranges as already described. This is cascade No. 3. Above this the river is more steady for one-half mile, when there is a widening of the channel near the mouth of a little creek from the north, and a fall of about 6 feet over one of the harder beds that protrudes above the rest. This goes diagonally across the stream. There is then a similarity in the stream to and beyond the old retaining wall of the railroad, a distance of nearly a mile, through which there is actually a steady ascent amounting in the aggregate, from the head of cascade No. 3 to the foot of the Thomson fall, to 70 feet. The Thomson fall is regarded as beginning near the 133d mile-post of the railroad (near the centre of section 8) and extending to the large island on sections 5 and 6. That part of it below the mouth of Otter creek which joins the river near the railroad bridge, south of the railroad, extending a distance of nearly a mile, is 30 feet, and is caused by the strike of the rock going directly across the river, causing it in several places to be suddenly contracted in width to 20 or 25 feet, through which narrow passages the river rushes with some fall and a swift current. The most of the fall is near the foot of the distance stated, but there is an irregular, rapid and rocky river all the way up to the railroad bridge that cannot consistently be subdivided, though it is more rocky at and near the

mouth of Otter creek. That part above the mouth of Otter creek, extending to the foot of the large island, is 35 feet. The larger part of this is near the foot of the island, but the river is a rushing torrent, in a rough, narrow gorge, sometimes split by islands all the way from the first fall to the creek.

The total fall, from the brink of Knife falls to the water at the foot of the lowest fall, N. E. ¼ section 15, township 48, range 16, by aneroid, is 500 feet, with an estimated descent of 50 feet more to the level of lake Superior.

"Different hydraulic engineers who have examined the river with a view to improving the water power have agreed on 2,000 cubic feet flow of water per second as the amount of water available at the minimum stage of the river, and they have calculated the total effective horse-power at ten projected dams below Thomson at 36,400, at the minimum flowage."—*Birkinbine.*

Southeastward from Carlton, about a mile and a half, at the rock-cuts on the Northern Pacific railroad, the same formation appears and presents some interesting features, which are more fully described in the description of plate 87. There is here a series of folding with axes that pitch eastward, the dip varying from 45° N., 10° W. to vertical, and again southwardly about 45°. One of the great dikes from the vicinity of Thomson passes through the rock at the most westerly of these cuts, 45 feet wide, running S. 30° W.

Northward from Carlton to Cloquet, and beyond, this slate formation is known to extend. It not only is exposed along the river banks, but forms low, sharp ridges in a manner quite similar to those seen near Carlton. These ridges are frequently cut by the St. Paul and Duluth railroad, Knife Falls branch. The rock usually dips south at the usual angle, as exposed along the railroad, but sometimes reaches 75° or even stands vertical. At Knife falls there is a series of heavy and arenaceous, firm strata which form the brink of the falls and, running under the river east and west, cause the islands seen there in the river. This coarser rock, along the north side of the islands, is interstratified with argillaceous slate, the latter having a slaty cleavage. At this point the sedimentary dip is south 3°, east 48°. There are ten beds of argillaceous slate which, with the exception of one bed of about 3 feet, do not exceed a thickness each of 18 inches, alternating with hard and gray quartzyte layers that have a little greater average thickness. These layers strike to the north of the main falls in the south channel. They appear on the east end of the island below the falls. A section across the channel, north and south through the brink of the falls, would be represented by the sketch below, looking about west. (Plate A.)

The slate beds are cleaved, but the quartzyte beds are not. The slaty cleavage gradually fades out in the quartzyte beds, but firmly cements them all together by an interlocking fibrous texture.

At the falls, which are on the N. W. ¼ S. W. ¼ section 13, township 49, range 17, and which face north, the brink running exactly east and west, the dip is 48° toward the south, and the rock consists of alternating layers of gray quartzyte and argillaceous slate. But there are two very prominent and persistent beds of gray quartzyte, one of which forms the brink of the falls, while the other is 40 feet below the falls and lies immediately over the section mentioned above along the northern side of the island. This lower quartzyte forms a spit of jointed rock that projects eastward just below the falls.

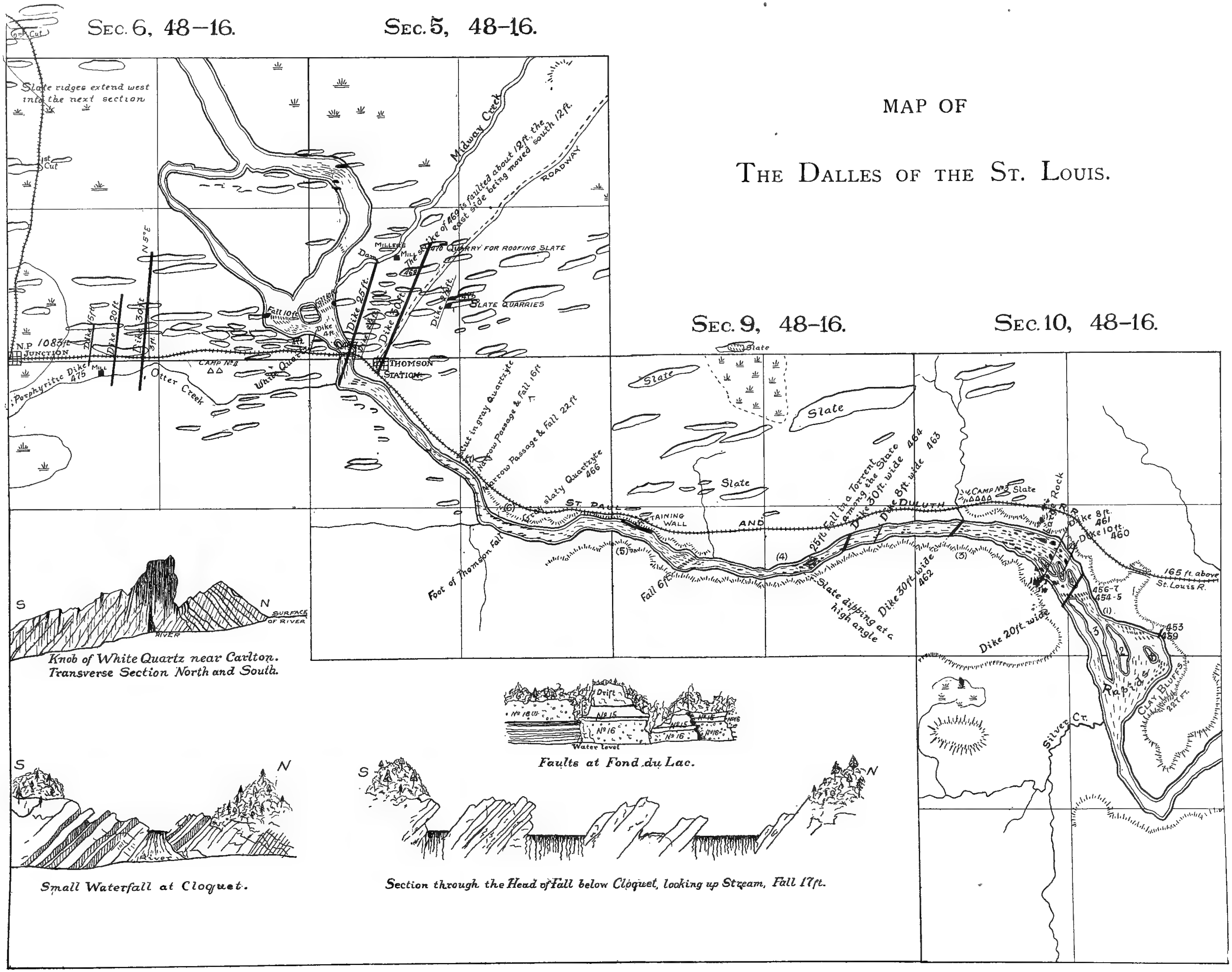
The descent of the water surface below the falls, in the first quarter of a mile, is about 20 feet. The river then turns southeast, the water constantly rapid, with large boulders, and a cascade of 3 feet at the distance of half a mile below the falls. Along the banks the rock is constantly exposed, rising in precipitous walls, at the cascade just mentioned, to the hight of 25 feet.

Another fall of 17 feet, in a horizontal distance of 300 feet, takes place at a quarter of a mile still lower, there being no perpendicular fall. There is a division of the stream into four channels by the strike of five different persistent beds in the formation; the water running in the strike of the intervening beds, the hard beds forming islands in the falls. The width of the river at the brink is about 230 feet, and a dike of about 200 feet crosses the river just at the head of the fall. This dike is destroyed by the river faster than the rock itself, owing to its frequent jointage; and the most rapid descent of the water is over the hardened beds of the formation on the east side of the dike, which runs north 5° east. The formation here dips south 60°. See figure on Plate A.

About one-fourth mile below this fall the river turns about south, so as to go directly against the strike of the rocks. The banks increase in hight, the dip increases in degree, and at three-quarters of a mile further there is a high rocky island (Fortress island) from the foot of which a portage trail sets out to Knife falls, on the west side of the river.* The larger part of the stream passes on the left of the island, the descent being eight feet over large boulders. At this place the rock of the country is wholly slaty, and although a short distance above the island there is a gradual change in the dip from 60° to 70°, and then to 90°, as the river exposes the beds, yet in viewing the island from the northwest downstream, there is, besides the slaty cleavage, a coarse bedding or jointage system visible on the east side of the island that seems to dip about 45° southeast.

*The portage trail which starts out here, known as "Knife portage" in distinction from "grand portage" which starts out from near Fond du Lac, is that traveled by Norwood, and by the explorers and geologists that preceded him. Du Luth was probably the first white man that passed over it. The route leads to the Mississippi and Vermilion lake. The party of Lewis Cass, accompanied by Douglass Houghton, traveled it. Schoolcraft passed over it at the same time, but he conducted a portion of the party of Gen. Cass from this point westwardly across Carlton county, uniting with the rest of the expedition again at Sandy lake. This route of Schoolcraft, according to his description, can be followed in a general manner, into the vicinity of the lakes in township 49, range 18, passing along the south side of them, thence through the swamps to the vicinity of Cromwell, leaving the county probably near Tamarack river. The Knife portage was the outlet for the immense fur traffic of the upper Mississippi region. It is well named *Knife portage,* because where it starts, and for some distance, the slates are thin, perpendicular and sharp like knives.

Map of The Dalles of the St. Louis.



At a distance the island itself, in its perpendicular walls, covered with red lichen, cut by joints that cause the slates to fall away in masses, looks like a basaltic island of igneous rock. But there is no igneous rock in it. It rises 50 or 55 feet above the water and is covered by small pines, among which are many Norways. The actual bedding either coincides with the slaty cleavage or dips southeast about 45°. The banks of the river are not so high as the island, but on the east side the rock rises fully as high a short distance back. Below the island the valley is deep and has high slaty walls, the water being steady for at least half a mile, at which point the "grand portage" begins, leading from the left bank south to the St. Louis near Fond du Lac.

Below Fortress island, where the first little rapid is seen, a dike crosses the river north and south. It is 40 or 50 feet wide, and is best exposed in the right bank some rods below the rapid. It appears again 30 rods further down and can be traced for half a mile along the right bank. The direction of this dike carries it across the railroad at Carlton near Paine's mill.

With various alternations and continually rapid water this character of the river continues past several islands, over numerous short cascades, to the railroad bridge at Thomson.

There are numerous exposures of the rock of the region along the Knife Falls branch of the St. Paul and Duluth railroad.

At one mile northeastward from Otter Creek station is a large area of slate and graywacke or quartzyte, which in general has a vertical slaty cleavage and cannot be separated from the Carlton rock. One of its strong bonds of alliance with the Thomson slates consists in the presence in both of black rusty spots due to the weathering out of calcareous masses or concretionary (?) accumulations. These black spots when they have lost their lime are a loose, spongy mass of siliceous seams that closely reticulate, retaining the coloring matter of the rock. Such spots are found abundantly on the ridge which is within the plat of Carlton, sometimes being small. They are seen there to coalesce, forming lines or eventually thin strata or laminæ, parallel with the sedimentary structure. They are also found in the Animikie slates at Thunder bay, as well as in the dark slates in the Sudbury district, Ontario, which have been mapped as Lower Cambrian by the Canadian geological survey. This is at the crossing of the Vermilion river by the Canadian Pacific railroad.*

At the point mentioned (one to two miles northeast from Otter Creek) the heavy sedimentary structure dips 45° toward the north, slaty cleavage is about east, 20° north, and slopes south so as to stand 80° from the horizon. Further northeast are several other large ridges that have shape and lithology characteristically like the Carlton ridges. Here are the same limy lumps, and further here the formation is sparingly stony and pebbly (2088). The stony lumps are siliceous and hard and stand above the surface when wasted by weathering. They thus contrast with the limy lumps which weather away faster than the rest of the rock, causing pot-like holes and black spots. The supposed pebbles, however, may have originated in the clayey sediment as claystones by some segregating process. They are sometimes almost flinty, and seem to fade out as if they were indigenous in the rock. They are sometimes surrounded by a coarser and lighter-colored scale; and sometimes a spongy layer is concentric within the pebbles, separating them into a nucleus and a body portion. Sometimes a pebble is evidently fragmental itself, embracing bits of black slate, or showing a banded sedimentary lining. The spongy brown layer is of the nature of the black calcareous lumps.

As to the dip of this rock, there seems to be irregularity and some obscurity, as it has indistinct structures that suggest dip in opposite directions. However, after some careful search very evident sedimentary bedding was found on the face of a ridge lying in the highway, which dips about 5° to 10° toward the south, 60° west.

Mahtowa. In the N. W. ¼ S. E. ¼ of section 5, township 47, range 18, near the central east and west line of the section, land of H. M. Waldorf, is a ridge of fine, rather massive rock which is sometimes slaty, rising about eight feet. Its trend is such that, if extended eastward without irregularities, it would strike about section 30, township 48, range 17, where a similar elevation is seen in the highway at about two miles southwest from Otter Creek, although not consisting entirely of similar rock. The west end of the ridge is different from the east end. The rock is in coarse jointage blocks, greenish and specked more or less with large pyrite cubes. A part of it is laminated schistose, especially along the east side, but most of it is massive, structureless and dike-like in appearance. The extent and width cannot be made out, only 20 or 25 feet being visible. This massive green rock is represented by No. 2079. Several low knobs in the vicinity are of the same rock. As an old eruptive it has been pressed and somewhat modified.

A few rods to the north of the last, at the roadside, is a low knoll of argillyte, or black slate, in which the slatiness dips at a high angle to the south, and shows a sedimentary banding that dips at about 45° toward the north. This black slate is filled with large pyrite cubes some of which are more than an inch on a side.

About 80 rods north from the ridge described and 50 rods east, a similar rock appears, but this is coarser, even conglomeratic, and resembling the conglomerate at Ely. This has been more pressed and shows some apparently fluidal movement, which is perhaps due to semi-fusion or plasticity of the sediments of a fragmental formation and the flowage of the softened material amongst the harder parts. The irruptive aspect shades off sometimes into the schistose and the schistose becomes pebbly with flattened forms. These flattened forms are coated with a darker, chloritic substance, in a manner similar to the coatings of the agglomerate masses at Ely. This rock, however, is much less agglomeratic than that described at Ely, but the resemblance to the old Keewatin greenstone of the state is quite striking. There is a rough structure, appearing to be the bedding of the conglomeratic portion, which has a dip about 45° southeast. This is also the direction of the generally fibrous structure. The

*Eighteenth Report of the Minnesota Geological and Natural History Survey, p. 54.

rock here has considerable amount of white quartz and coarse pyrite crystals, some of the latter being an inch on a side. This place is about in the line of strike from the above locality of 2079, in an easterly direction, *i. e.* S. E. ¼ N. E. ¼ section 5, township 47, range 18. Rock 2082 represents one of the coarser masses which are irregularly separated and surrounded more or less by finer and fibrous schist. These are not certainly always as isolated parts, but independent layers are composed of such rock. The whole is certainly a part of the greenstone of the Keewatin with the same indefinite characters. It has a conspicuous, apparently bedded, more or less nodular, or agglomeratic structure, that dips nearly east at an angle of about 40°. Other phases are represented by rocks 2083–85.

North of this belt of Lower Keewatin, about three-quarters of a mile, runs a ridge of different rock. This is like the Carlton rock and crosses the railroad and the highway about a mile and a half southwest from Otter Creek station. It appears S. E. ¼ S. W. ¼ section 29, township 48, range 18, (2080), where it affords a light-weathering but fine-grained graywacke, having a coarse jointage and siliceous composition. It is thick and massive in bedding, and so extensive that it is but rare that a sedimentary banding can be found. It also contains black calcareous snow-shoe tracks, so-called, as seen in the rock at Carlton. The dip is north 45° (2081). Sometimes this rock appears, at a little further north, in the form of low east-and-west ridges, with dip nearly vertical or toward the south. It is evident from the difference in the direction of strike, the different lithology and structure, that this ridge is another formation from that lying to the south which is seen at Waldorf's, near Mahtowa.

At the S. W. ¼ section 4, township 47, range 18, is a fissile, dark-colored schist, whose structure dips nearly east 45°. It occurs along the creek. The foliation is doubtfully the sedimentary dip.

The Carlton rock appears at N. E. ¼ section 35, township 48, range 18, in a low ridge having black calcareous spots, also at Atkinson, at the centre of section 25, township 48, range 18. At the latter point is some vein quartz, in form of foliæ. This rock dips north about 30°.

Where this range crosses the railroad two miles south of Otter Creek it is low and inconspicuous, and although the rock is not much different from that described, it has an imperfect vertical slatiness.

At Barnum is a low ridge, west of the station, showing a cut of three feet by the railroad. It is fine slate, becoming coarser and approaching a fine graywacke. The dip is about 10° toward the south, but the face of the cut shows many minor undulations, with quartz in cavities.

At Moose Lake is a micaceous, firm graywacke quite similar to that seen at Barnum. While it appears, when weathered, very much like some gray slates of the Animikie seen on Pigeon point and elsewhere, it is apparently an older rock than the Animikie, being distinctly micaceous and more crumpled than the rock about Carlton. This rock occurs as boulders, which are scattered plentifully about Moose Lake.

A rocky hill occurs on the N. E. ¼ section 22, township 46, range 20, near Gillespie brook, on land of Ed. Lund, supposed to be of the same formation as the rock at Moose Lake.

Kettle river valley. Some exploration for gold was done in the schists at the mouth of Otter brook (sec. 16, T. 46, R. 20) by Cunningham and Miner, a few years ago. Their shaft is said to have been 30 feet deep, and explored further with a diamond drill. That which attracted their attention was a lot of white quartz more or less mingled with pyrite, which also permeated the rock itself, existing as filmy coatings in the cleavage planes and other joints. The rock is a compact sericitic schist, quite siliceous, with scattered irregular lumps of quartz. It rarely becomes so coarse as to warrant the name graywacke. It is unknown how much gold was taken out, but probably not much; yet there is no known reason why it might not exist here as well as at Rainy lake.

In the bed of the creek is the principal outcrop of the quartz vein, but the quartz occurs very irregularly in the schist.

Below the mouth of the creek about 15 rods the formation appears in the right bank of Kettle river. Here are several alternations of soft, fissile slaty rock and a gray, fine rock which might pass for a quartzyte, from some beds of which are found numerous boulders in the drift all about this part of the county.

On the right bank of Kettle river a quarter of a mile below the centre of section 16, township 46, range 20, a low outcrop appears of rock like that seen at Otter brook, dipping in the same way. This is unnconformably overlain by a basal conglomerate of a loose texture, mainly friable sandstone but embracing pieces of the underlying schist.

About a quarter of a mile above the mouth of Gillespie brook is an outcrop in the left bank of Kettle river. This rock, which rises about 18 feet in the bank, is very singular and presents but few and faint characters that ally it with the schist formation of the region. It is a shaly schist, rusty-green, but with glittering sericitic scales on the planes of the partings. It has no persistent conspicuous dip, but in all parts it breaks by irregular seams and joints in roughly lenticular small blocks, by means of which it forms a talus, yet in one place, over a distance of 12 to 20 feet an indistinct presence of a jointage in a direction south-southeast, seems to be visible, giving it a structure coincident with that seen in the schists of the region. Again, about 10 rods further down, the rock being visible continuously, there is apparent a nearly horizontal structure, and the appearance suggests some Cupriferous (or Keweenawan) shales. In some of the talus fragments, however, are remnants of vitreous vein quartz, which is not a feature of the Keweenawan shales, but characterizes the schists of the western part of the county. The rock therefore must be considered a rotted outcrop of the older schists of the county.

About 25 rods below the mouth of Gillespie brook, on the right bank of Kettle river, a similar rock outcrops, but here it shows more plainly its stratigraphic alliance with the schists. This rises about 20 feet above the water, is roughly and lenticularly separable into homely small pieces, but is plainly a fine-grained mica schist, or sericitic schist. It is sometimes ridged and crumpled, showing small faults and sliding planes. It is

rusty and crumbling, and might, at a hasty glance, be taken for a fine crumbling sandstone or sandy shale. In numerous places about the mouth of Gillespie brook this mica schist appears in the banks of the streams, and also rises elsewhere as little hills. Its quartz has attracted attention for gold, and some shafts have been sunk from 10 to 20 feet. It is exposed conspicuously in the left bank of the Splitrock creek, a short distance above its mouth. A gray and greenish schist appears at the surface on S. W. ¼ N. W. ¼ section 19, township 47, range 21, in the form of angular blocks, in many places, but does not afford favorable exposure for examination. Large surfaces that are apparently of the bedding, dip north 25° west. They are wrinkled and irregular with cavities, with some vitreous and smoky quartz. The rock appears micaceous and talcose.

Puckwunge (Potsdam) Conglomerate. A coarse and pyritiferous quartzose conglomerate forms conspicuous outcrops on section 1, township 48, range 16, at the shore of St. Louis river, which represents the fragmental base of the Keweenawan formation. This also appears further north along the banks of the creek that unites with the St. Louis on section 1. It lies in depressions in the old slates, being thicker in some places than in others. This rock also is in outcrop on the S. E. ¼ section 2, township 48, range 16, on the St. Louis. Its total thickness is nearly 100 feet.

Owing to the importance of determining well the stratigraphic position of this conglomerate, it has been examined several times, and comparison has been made on a broad scale, with the known stratigraphy of the Keweenawan in the western portion of the lake Superior valley.* One result of this study is the assignment of this conglomerate to the base of the Potsdam, below the Manitou igneous rocks.† Its pebbles are chiefly derived from quartz veins in the underlying slates, and from the quartzytes and graywackes of the same formation. Upwardly the material becomes much finer, constituting a white sandstone, and even a light-colored shale. It changes then to a red shale, and at a somewhat higher stratigraphic horizon it is charged with eruptive materials, making a characteristic Manitou conglomerate. There is no marked change in the dip, but, so far as observed, the strata are conformable from the lower conglomerate into the other.‡ There are reasons, however, to infer that great physical disturbances took place in the immediate neigborhood during the accumulation of this fragmental series—indeed that the eruptive epoch of the Manitou division of the Keweenawan began, and perhaps culminated and declined before all the sandstones next overlying were formed, those sandstones themselves being probably closely linked with the waning stages of the Keweenawan. This question is more fully presented in the chapter devoted to the Duluth plate (No. 88).§ The igneous rock, which rises into quite conspicuous hills a little eastward from this outcrop (at Short Line Park), which is apparently a part of the gabbro range seen at Duluth, was probably of prior date, but no debris from it can be found in this

***Crucial Points in the Stratigraphy of the Lake Superior Region.* N. H. WINCHELL, Am. Geol. 1895, vol. xvi, p. 150.

†The Manitou igneous rocks are those of the upper division of the Keweenawan. Compare the Duluth plate, chapter xxxi.

‡Owing to the rapidity and depth of the river and the precipitous nature of the cliff at the exact transition, no close inspection has been made of the actual transition.

§See also *American Geologist*, vol. xvi, p. 78, 1895.

coarse conglomerate, probably because of the more destructible nature of this rock compared to the quartz pebbles that went to make it. But somewhat higher in the series of these fragmentals abundant eruptive materials are disseminated, and even red, crumbling eruptive conglomerates were formed, comparable to those seen at the mouth of the Manitou river and elsewhere on the north shore of lake Superior. This change indicates that active eruption was going on in the immediate vicinity—eruptions of the Keweenawan epoch. This alternation of the nature of the sediments is continued further, imparting a red color to the shales and sandstones, until the dying out of the eruptive activity. The advent of this Keweenawan (Manitou) epoch of eruption is recorded not only in the sudden change in the character of the sediments in the St. Louis valley, but also in the basic dikes that cut the gabbro hills at Short Line Park. This formation being mainly outside of Carlton county, it will be found explained in the description of plate 88, the Duluth plate.

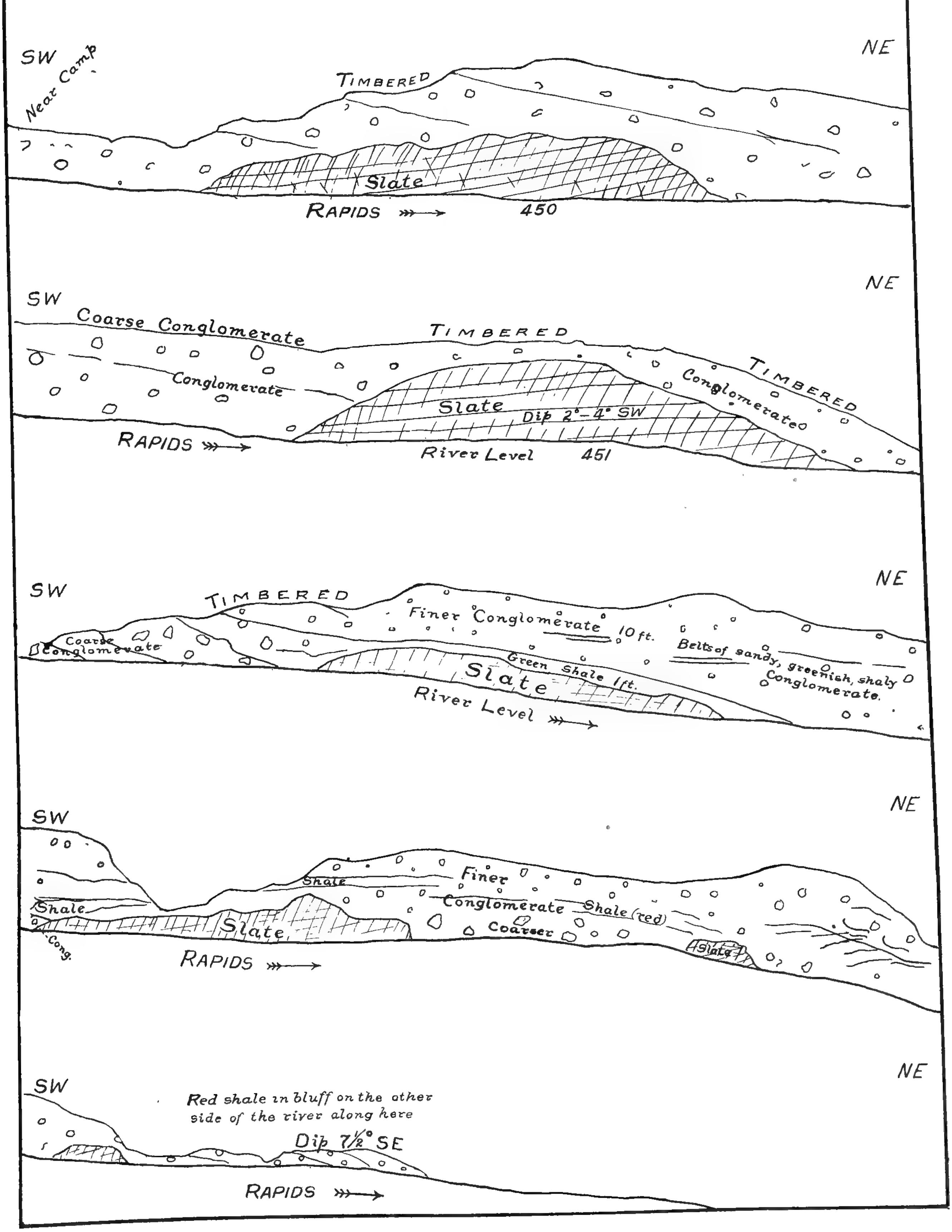
Detailed description. The conglomerate seen on section 1, township 48, range 16, is hard, pyritiferous and pebbly with coarse quartz pebbles, of which it chiefly consists. It dips, with the red beds overlying, about 10° east of south by compass. Some of the pebbles are two or three inches across. Some are of milky quartz and some are translucent. Some are black or gray. In some places nearly one-half is directly referable to the underlying slate formation; indeed there is nothing in it but can be so referred. Just above the junction of the two creeks there is a blind vein of calcite, about two inches thick, running north and south in this conglomerate. The conglomerate extends a few rods along the creek, both branches, and before it disappears, which it does by rising in an incline along the left bank in accordance with the dip, it shows about eight feet of bedding, and within a distance of about two rods the Thomson slate formation appears in the bed of the creek and soon forms a considerable exposure along the left bank. The slates stand nearly perpendicular as the weathering separates the cleavage planes, and the strike east and west as at Thomson. At this place the appearances indicate that the conglomerate lies in depressions in the old slate surface.

The following sections illustrate the manner of superposition of the conglomerate on the slates. The sections extend from "Bridge No. 2" down stream to the point of final disappearance of the coarse conglomerate. (Plate B.)

This quartz conglomerate, in its upper parts, includes lenticular spots of shaly sandrock and of red conglomerate. At the bank of the St. Louis this conglomerate forms the low shore, and its upper surface is washed by high water, dipping into the river at an angle of 8°. It then stops abruptly, by a fault, and the shore is occupied by a red and spotted green shale, of which the dip is more toward the south. Where the conglomerate is broken off it is highly pyritiferous, and cemented into a compact rock, and at the very fracture the whole is changed and vitrified, making a firm greenish quartzyte. In the bluffs on the opposite shore may be seen four separate faults crossing the red shale and sandstone beds from the top to the bottom. This is just opposite the point of faulting of the conglomerate on the left bank. (Plate A.) After the abrupt disappearance of the conglomerate, the left bank, in ascending the stream, is found to be occupied by a low exposure of layers of this green and red shale belonging to some higher portion of the section, while in the right bank opposite is a bluff with an average exposure of 10 feet of rock consisting of red shale and shaly rock with varying dip. All at once the coarse conglomerate rises again, but not so suddenly as it disappeared, and forms the shore to the place where the slate formation is found underlying it unconformably. Where the conglomerate reappears it seems not to be faulted, but bent and somewhat broken upward, the shale beds above also being somewhat bent and compressed, though maintaining a green color where in contact with the conglomerate. The change of level is about two feet, and it is expressed on the opposite shore by undulations in the strata. It is about forty rods above this point that the slates first appear under the conglomerate.

The lower portion of the conglomerate is coarser, though containing about the same materials as the last, with the exception of layers of sandrock. The white quartz pebbles are sometimes six inches or more in diameter. Some are of gray, coarse grit, and some are pieces of the underlying slate, showing this slate must have been about as it is prior to the deposit of the conglomerate. On the other hand it is to be noticed that a roughly slaty manner of disintegration passes upward into the conglomerate from the slates, where the weather has acted on the two at that horizon the pebbles and cement falling off in slabs or lumps that are elongated in the direction of the slatiness of the slates and parallel with them, as if the cause that operated to produce the slatiness had taken effect since the deposition of the conglomerate, and had resulted in a similar, imperfect.

Superposition of the Puckwunge Conglomerate on the Thomson Slates St. Louis River.



structure in the overlying rock. In some places a layer of green shale lies between the conglomerate and the slates. It is a foot thick. The coarse, pebbly quartzose conglomerate has an estimated thickness of 100 feet.

Pebbles from the soft, red and crumbling conglomerate that overlies this, consist almost wholly of eruptive basic materials. This upper conglomerate is well exposed at the mouth of the creek entering the St. Louis river S. W. ¼ section 1, township 48, range 16. These pebbles seem to show that this conglomerate is later in date than the traps, amygdaloids and porphyries of a part of the Keweenawan. Yet some of these pebbles are not from the eruptive Keweenawan, and came apparently from the Animikie, and one is a piece of iron pyrite which *itself embraces grains of rounded quartz and fragments of pyritiferous grit* quite similar to the pyrite found in such abundance in the underlying quartzose conglomerate, which itself contains no Keweenawan pebbles. Such a piece of pyrite has no known source which can be invoked here, except from the pyrite-bearing quartzose conglomerate underlying, which appears in the valley a short distance higher up the St. Louis. The strong contrast in the pebbles from these two conglomerates, and especially the occurrence of this pebble of siliceous pyrite in the upper one, points to the existence at this place of two conglomerates separated by an epoch of great dynamic and volcanic disturbance such that the older strata were ruptured and their debris was mingled in the younger. In short, the lower conglomerate is the bottom of a great quartzyte or sandstone formation (Potsdam) in the midst of the accumulation of which the Manitou division of the Keweenawan eruption took place, changing the character of the later fragmentals by the admixture of a large percentage of eruptive debris, this admixture occurring at irregular intervals, and finally ceasing entirely. The calcite vein already mentioned, as well as the compact, hardened condition of the older conglomerate, and the fact that the slaty structure of the underlying slates produces a roughly similar slaty disintegration extending for some distance upward into it, not only point to the production of the slatiness since the formation of the conglomerate, but exclude the rock exhibiting such characters from a date later than the Keweenawan eruptions, for none of these characters have been seen elsewhere in the lake Superior basin in any clastic rock younger than the Keweenawan eruptives.*

The late Keweenawan or Manitou eruptives. Although there is no known exposure of these rocks in Carlton county (unless the diabase dikes be considered Manitou) there is little doubt that they underlie a considerable area in the southeastern part of the county. They occur near the southern boundary, in Pine county, section 25, township 45, range 17, and in Wisconsin about a mile southeastward from the southeastern corner of the county, or, more precisely, southeast corner of section 6, township 45, range 15. The formation is mentioned here in order to complete the geological sequence, these eruptives separating the foregoing conglomerate and light sandstone from what followed by a pronounced physical change which causes the later sandstones to assume a red color.

The western sandstone. This designation was applied by Irving to all the sandstones westward from Keweenaw point to the St. Louis river, which he supposed to be non-conformable upon the Keweenawan; and in the Keweenawan he placed a lot of red sandstones, succeeding to the traps, which, with the traps, he believed had been upheaved and eroded extensively before the deposition of the western sandstones. Using this term, we cannot adopt Irving's idea of their stratigraphic relations. As already stated, the conglomerate and the light-colored siliceous sandstones immediately succeeding to it, in the St. Louis valley, are earlier than the later traps, but the red sandstones and conglomerates, involving by far the larger amount of the sandstones of the St. Louis valley, are more recent than the same traps, and followed the traps immediately,—indeed are interbedded with the traps, as will be seen by consulting the description of the deep well at Short Line park, Duluth plate.

*The slaty cleavage noted by Sweet at the falls of Black river, Douglas county, Wis., is not a parallel case, since it is ascribable to local tilting and faulting, and it, even, is of date earlier than the close of the Keweenawan agitation. Geol. Wis., vol. iii, pp. 340-347.

They are, therefore, strictly a part of Irving's Keweenawan. They are at the same time, in fact, inseparably united with Irving's western sandstones and really constitute his western sandstone as described by him, and are, hence, nearly on the horizon of the Hinckley sandstone, into which they graduate upwardly, all of which he considered Upper Cambrian. In other words the erosion interval, supposed by him to exist between two sandstones, one pre-Cambrian and the other Upper Cambrian, disappears entirely, and the two sandstones are shown to be one and the same, and later than the traps, though at the bottom interbedded and variously affected by the late Keweenawan eruptives. The term western sandstone is, therefore, a geographic designation for a limited portion of that great formation which Dr. Douglass Houghton styled Lake Superior sandstone.

These beds outcrop in the valley of the St. Louis in sections 1, 2 and 12, township 48, range 16, on the south bluff of the river, where they are rapidly being eaten into, in consequence of the southeasterly dip, by the current of the river. They thus maintain a perpendicular bluff as the undermined masses successively fall off. Viewed from the left bank they are seen to be faulted at four places, presenting the aspect seen in the figure, plate A. They were struck at the bottom of the deep well at Wrenshall, at a depth of 355 feet, about 80 feet above the level of lake Superior. It is seen again in the loop of the Blackhoof river, in township 47, range 17, and near Barnum, on the south sides of Bear and Cub lakes, and in the southern banks of Moose lake. Westward from here an isolated remnant of the Hinckley beds has been mentioned in the valley of Kettle river.

The most of this rock is red, but the further toward the southwest it is examined the more white and siliceous it becomes, while at Fond du Lac (a short distance east of the Carlton county line, in the St. Louis valley) some of its upper layers are quite light colored.

Hinckley sandstone. The sandstones that succeed the Manitou eruptive epoch are very thick. They are interbedded with much red shale, and they gradually become light colored. During their accumulation there was a progressive subsidence of the land in the region of lake Superior, bringing the later, light-colored sandstones over more and more extended areas, of the older rocks. It was by this means that the Archæan schists in the western part of Carlton county were covered by this sandstone. If a continued vertical section of this sandstone could be measured, including all its strata, the thickness would probably be not far from a thousand feet, and in Wisconsin it has been estimated at several thousand feet. These clastic strata are all certainly thicker on the south side of lake Superior.

They present but slight exposures in Carlton county and it may be still a question whether the outcrop here referred to is not instead of the age of the Cretaceous.

Details of observation. On the right bank of Kettle river, a quarter of a mile below the centre of section 16, township, 46, range 20, is a basal conglomerate of a light-colored sandstone. The total exposure amounts to only about 10 feet vertical, and of that thickness the whole cannot be seen at any one spot. The underlying rock is the Keewatin, like that seen at the mouth of Otter brook. The great majority of the included pebbles are of the Keewatin adjacent. They are not much rounded, but seem to have been buried nearly *in situ.* Other pebbles are of white quartz, also angular. In some places is a dark red or brown-red color apparent in the conglomerate, and in places it varies to a white sandstone. In the drift overlying, which is gray and quite gravelly, are many kidney iron ore pieces, evidently from the Cretaceous, but these do not appear, so far as noticed, in the sandstone. It is evident that the Cretaceous, as well as the Archæan, contributed to the formation of the drift sheet of the region. Other traces of the Cretaceous in Carlton county are mentioned in connection with the description of the drift.

The Drift.

The drift of the county had a compound origin, and after first deposition it was modified by the action of lake Superior in the southeastern part of the county,

when that lake stood about 500 feet higher than it does now. There seems to have been a northwestern and an eastern source. Characters that point in both directions are found throughout the county. It is probable that the ice-lobe that occupied the basin of lake Superior operated, at the last, later than the ice-sheet that moved in general from the north or northwest. There is no very evident morainic belt that marks any local halting place for the great early glacier, although as it waned it is probable that its union with the lake Superior ice-lobe as the latter began to take individual shape and motion, was marked by a greater accumulation of drift than was elsewhere deposited. Such a medial moraine may be expressed by the hilly tract of drift that extends across the western part of the Fond du Lac Indian reservation southward as far as Mahtowa. In general, however, the western half of the county is so smooth that it seems unlikely that any morainic belt can be safely located there. The only exception to this statement is found in the western part of township 46, range 21, where a morainic belt about a mile wide runs north and south across the western portion of the town, extending into Aitkin county. But even this may be an interlobate moraine, since boulders of gabbro which must have been carried from the east are found along the Kettle river about six miles further east. The distribution of gabbro boulders, however, is not an unexceptionable guide to the limitation of the lake Superior ice-lobe except within the immediate vicinity of the gabbro outcrops, for such boulders are found in the drift as far south as Minneapolis, where they must have been carried by the main glacier. Judging from the fact that large numbers of gabbro boulders are found further north, and beyond the limits of Carlton county, it is safe to conclude that the lake Superior ice-lobe, having in the main a westward movement, at least along its northwestern border, must have covered the most of Carlton county, and in its retirement it left a remarkable and interesting series of records.

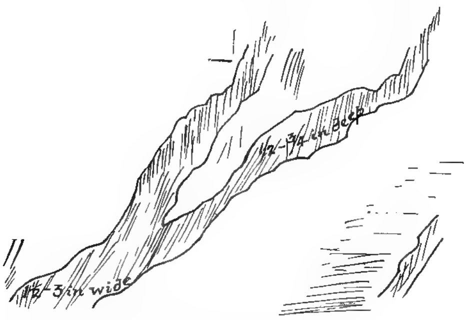
Glacial marks in Carlton county.

Half a mile northeast of Otter Creek station, on graywacke and argillyte,	(True meridian)	N. 55° W.
Same place, another knob, short heavy gouges,	" "	S. 45° W.
Same knob, long, isolated heavy cuts,	" "	N. 60° W.
Same knob, heavy cuts, but rather few,	" "	N. 45° W.
Same knob, most abundant,	" "	N. 60° W.
[These are all on a slaty knob whose surface slopes N. about 20° E., the inclination being 30° from the horizon.]		
Thomson, 15-20 rods southeast of the depot,	" "	N. 80° W.
Thomson, 3-6 rods east of the last,	" "	N. 52°–55° W.
Thomson, 10 rods west of the dam,	" "	N. 70° W.
Near St. Paul and Duluth railroad, 1/8 mile west of the St. Louis river, mostly intersected by the next.	" "	N. 70° W.
Near St. Paul and Duluth railroad,	(True meridian)	N. 55°-60° W & 80° W.
About 15 rods west of the last, mostly,	" "	N. 80° W.
with others equally distinct crossing on the same surface,		S. 60° W., S. 35° W., S. 10° W., S. 20° E., and S. 30° E.
Carlton, on the street leading to Thomson,	(True meridian)	N. 80° W.
One mile west of Carlton, near Northern Pacific railroad,	" "	S. 50°–65° W.
Last railroad cut, 1 1/2 miles southeast from Carlton,	" "	N. 65° W. & N. 45° W.

Two rods southeast from the last, numerous,	(True meridian)	N. 45° W.
Again, two rods further southeast, abundant,	" "	S. 80° W.
intersected by S. 15° W., S., and S. 45° E., each of these courses being represented by only two or three glacial gouges.		
About three rods further southeast, many very clear striæ,	" "	due W.
At 25 feet further southeast,	" "	S. 85° W.
and partly S. 80° W. and due W.		
The same westward striation is also shown on this southwest side of the cut in other places within two rods southeastward.		
On the northeast side, at the crest of the cut, about 10 rods southeast from the last, plentiful,	" "	N. 80° W.
Crossed by short gouges S., S. 20° E., and S. 45° E.		
These cross-markings are two to six inches long and numerous.		
About 25 feet northwest from the last the well-preserved main striation is	" "	W. to S. 85° W.
crossed by a few short glacial marks,	" "	S. 20° E. & S. 45° E.
Top of the hill (most eastern) cut by railroad, 1½ miles southeast from Carlton,	" "	S. 28° W.
Knife Falls, on graywacke,	" "	N. N. W.

Near the centre of section 8, township 48, range 16, in the valley of the St. Louis, the slates exhibit interesting striæ. The direction of coarse marks is south 28° west, but there are small areas near that have both a northerly and southerly direction, and also a more westerly bearing, as if the abrading force had a zigzag movement, and an interrupted application. There are also heavy glacial marks that pass west-northwest, on the same surfaces that are coarsely striated a few degrees west of south, and north and south.

One large groove in particular, running southwest, has a slight curvature, and is isolated. It is over two inches wide, and cut as by a rounded gouge to the depth of about an inch, tapering and running to nothing at each end, its length being 3¾ feet. The stone that made it must have had at once a forward and rotating motion, since there are subordinate transverse striæ that cease on the northwest side, and others that begin on the southeast side, thus giving the whole groove a slight curvature. Another groove, similar to this, exhibits still plainer the same kind of shifting of the boulder, but in the opposite direction. Thus although the real aggregate motion was in the direction of the striæ, yet the groove actually cut varies from it in some places about 15°. The surface here described is illustrated by the figure above. Two large grooves are alongside, and toward the west they coalesce, one being cut probably a little later than the other.



GLACIAL GOUGES

FIG. 1.

The earliest outlet of the lake Superior basin. It may be assumed safely that the drainage from this ice-lobe was toward the south. As long as it passed beyond the rim of the basin in which it lay, its waters were carried away by several valleys to the Mississippi, viz.: by the Brulé, the St. Croix, the Kettle and the Prairie rivers. When it was shrunken so that it lay wholly within that rim a lake rose round its

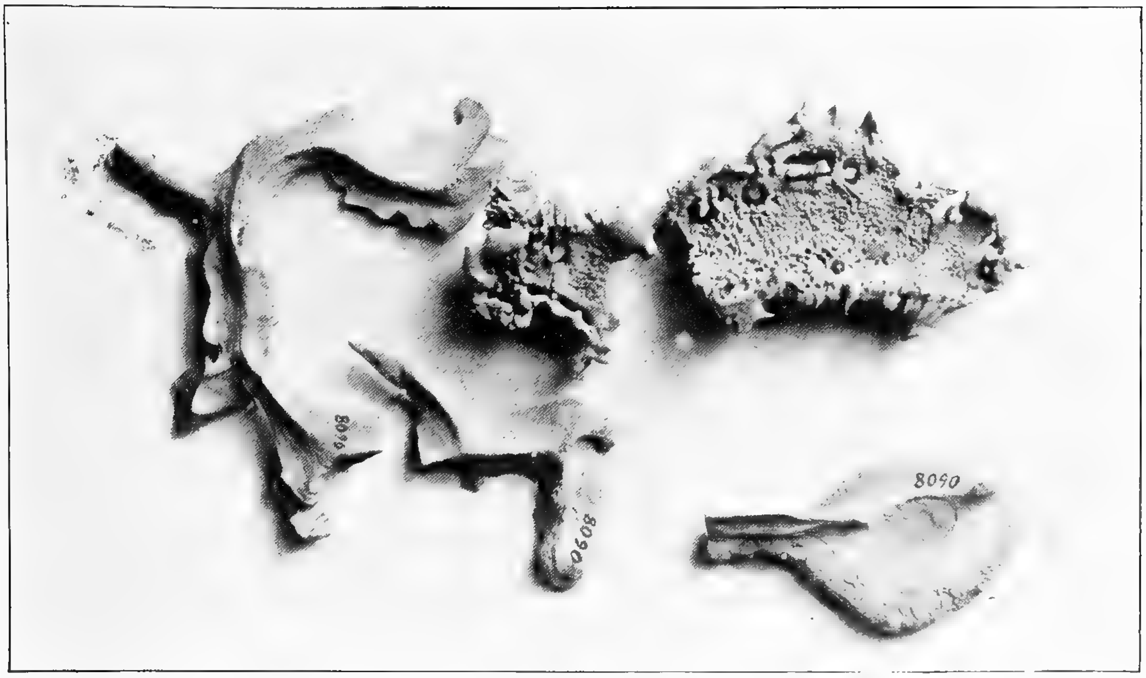


FIG. 1. LIMY CONCRETIONS IN THE BRICK CLAY AT WRENSHALL. (p. 21.)

FIG. 2. ROCHES MONTONNÉES NEAR CARLTON. SUMMITS OF RIDGES OF SLATE AND GRAYWACKE. IN THE BACKGROUND IS THE FLAT-TOPPED DELTA FORMED IN LAKE ST. LOUIS. WINTER SCENE. (p. 19.)

margin and found its discharge at the lowest pass. As the ice withdrew further and further the lake increased, and if lower passes over the rim were uncovered this lake immediately was drained to the level of such lower passes. In the course of this process the ice-lobe appears to have been for a time nearly stationary in its retreat, having its margin crossing the centre of Carlton county. It then formed the morainic belt represented on the plate of the county, which passes through townships 46, 47, 48 and 49, ranges 18 and 19 west. At this time the drainage of the western portion of the ice was through the Moose valley to the Kettle river. There is an ancient channel, more or less boulder-paved, through which the St. Paul and Duluth railroad has been built, extending from Carlton to a short distance south of Moose lake, where the sand plains about Sturgeon lake commence. The glacial stream which filled this valley here unloaded its debris. For some time the waters of the St. Louis valley were prevented, by the lake Superior ice-lobe and its terminal moraine, from following the present course of the St. Louis river below Carlton. As the ice retired this drainage course was somewhat augmented and individualized, but it shifted its position from the small valley at present occupied by the upper waters of the Moose river (at Mahtowa) to a position southeastward from Mahtowa, where it remained sufficiently long to make a very pronounced and characteristic channel in the still slowly accumulating drift deposits. This channel, as represented on the plate, crosses the morainic deposits diagonally and unites with the Moose valley at Barnum. Its highest point, over which the infant Superior had its first discharge, is 523 feet above the present level of lake Superior. This outlet was occupied until the next lower outlet was opened, a period of time probably comparatively short. The small lake that was thus drained was a marginal one and the ice-lobe had its western limit quite near. That is to say, since the next lower outlet must have been still obstructed, viz.: that existing in township 46, range 18, the ice margin must have passed obliquely across the county, and the small lake was an elongated one, covering not more than 30 square miles. It included the central and northeastern part of township 48, range 17, the eastern part of township 49, range 17, and probably some of the western part of township 49, range 16. The region drained by the St. Louis, whether ice-covered or not, found its discharge by this old channel, through this narrow lake. (Plate C.)

As soon as the second "waste wier" was uncovered this lake was immediately drained entirely. For a period whose length there is no means of measuring the St. Louis flowed to the Mississippi by way of the Otter creek valley and the Blackhoof, reaching this lower outlet by entering first another lake whose size was destined to grow to considerable dimensions. This later lake covered the Nemadji valley, extending northward so as to include the St. Louis valley, at least that portion of it

that lies eastward from the east line of Carlton county. Its exact northern boundary in Carlton county has not been determined. In the vicinity of Carlton and northward and southeastward there is a confusion of beaches and plateaux which it has not been possible to individualize by detailed study. Some of them belong to the old St. Louis, some to the earliest lake, and some to the Nemadji lake.* The outlet of glacial lake Nemadji is quite marked. It passes through sections 16 and 17 township 48, range 18, where a boulder-paved swamp extends from the headwaters of Portage river to those of the Nemadji. Brush-lined sloughs on section 17 indicate that water flows both into the Nemadji and into the Portage. This valley is comparable to that which connects lakes Traverse and Big Stone, the ancient drainage course of lake Agassiz, at the western side of Minnesota. It lies about 100 feet below the upland, at the farm of L. C. Nighsonger, S. W. ¼ section 18, township 46, range 18, and there it shows a boulder-strewn bench which rises about 15 feet above the bottom. It is not likely that this represents a terrace, but is caused by an unusually stony spot in the till through which the channel was formed. The channel throughout is about a quarter of a mile wide at the bottom, and the boulder-pavement is frequently covered with muck.

During the prevalence of the Nemadji lake the many streams that enter the west end of lake Superior were carrying into it a large amount of sediment. This process continued with very little change while the outlet was through the Bois Brulé valley to the St. Croix. This sediment was derived from the freshly laid sheet of drift that covered the country round about. The till that underlies the Nemadji valley is red, and was derived very largely from the rocks of the Keweenawan toward the east, but the sediment that lies on it, forming a laminated clay to the depth of 5 to 50 feet, came more generally from the west. On the weathered surface this lacustrine clay is red, much like the red till, but at Wrenshall, on the Northern Pacific railroad southeast from Carlton, its color changes to gray at a depth of a few feet, and the bricks that are there made from it are of a light cream color. In that particular it is so much like the gray or "blue" clays of the western part of the state, which have a large ingredient of Cretaceous debris, that they seem to have had, in part at least, a common source. It has been inferred, therefore, that probably the Cretaceous formerly extended over the region and has been destroyed by the severity

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* Mr. Upham has often mentioned the "Western Superior Glacial lake," having its outlet at a still lower level by the Bois Brulé and upper St. Croix rivers through western Wisconsin, but as these outlets are higher they drained lakes having an earlier date, which should receive, according to the current practice of Pleistocene geologists, distinguishing names. The earlier one may appropriately be called the *St. Louis* glacial lake, and the later *Nemadji*. Of these two outlets the lower one is the more distinct. It is a curious coincidence that its point of passing across the divide in township 46, range 18, has the same elevation as given (Geol. Nat Hist. Sur. Minn., vol. ii, final report, p. 642) by Mr. Upham for the outlet at the Bois Brulé. As, however, this beach line is known to ascend toward the east at the rate of at least three inches per mile, the distance separating these outlets being about forty miles, it is reasonable to place that outlet, when it drained lake Superior, at least 10 feet lower than the Nemadji outlet, and it may have been considerably more. No accurate levelling has been done to ascertain the elevation of the Nemadji outlet. It is only by a series of general aneroids and eye-sketching that its altitude is made 1,070 feet.

"Near Holyoke, which is about 30 miles west of the outlet at the head of the Bois Brulé and St. Croix rivers, the successive lake levels, indicated by the beach ridges observed, and provisionally referred to the Western Superior lake, are about 520, 500 and 455 feet above lake Superior, corresponding well with the slightly inclined planes of the Duluth and Mt. Josephine shores, and indicating the lowest water surface of about 455 feet at the outlet." UPHAM. *Twenty-second Annual Report, p. 59.*

of the glacial abrasion. This is not the only indication of former Cretaceous strata in Carlton county. In the nooks of the Thomson slates, as cut by the railroad near the St. Louis river, occurs a fine blue clay lying below a foot or two of fine laminated red clay; and at some drift bluffs on the St. Louis, north from Carlton county, a blue stratified clay lies below laminated red clay. In the western part of the county, furthermore, Cretaceous debris, in the form of the well-known limonitic crusts and kidney iron ore balls, is quite common along the Kettle river.

Detailed descriptions. Brick clay at Wrenshall. In the vicinity of Wrenshall are five brick-making establishments, viz: M. J. Rushfeldt, Jaggar & Hanft, Fred Habhaggar, The Kelly Brick and Tile company and the Duluth Brick and Tile company. The clay, which is essentially the same at all these establishments, has, at the pit of the Kelly Brick and Tile company, a thickness of about 40 feet, of which the lowest 30 feet are blue and the rest red, or brownish yellow. According to Mr. Kelly the well which was here sunk to the sandstone, 350 feet from the surface, passed only through gravel and sand after penetrating the laminated clay. This, however, is exceptional, if not improbable. Water rises to within 85 feet of the surface.

The surface of the laminated clay, for the depth of a few feet, is more or less broken up and mingled with pebbles, due probably to the action of the retiring beach line of the lake and floating ice. This is the condition of this clay sometimes to the depth of 10 or 12 feet. Such change makes it a "pebbly clay," and this may have been the cause of some other "pebbly clays" of other regions; at any rate this pebbly condition fades out downward *gradatim* as the clay loses its stratification upwardly.

On the very surface, moreover, are other signs of beach action, such as gravel, coarse and fine, and a sandy gravel that in one place extends downward for six or eight feet below the upper level of the clay.

In the clay are rare stones, one of which was seen two and a half feet across. They are usually rounded, and were probably dropped by icebergs or by floes while the clay was being formed.* Such stones might be carried from the beach at the present time from the vicinity of Duluth, and therefore do not here prove glacial conditions. If, however, they are found near the line of junction of the laminated clay with the till, they might have been deposited there by the glacier as its margin retreated.

The change from gray or blue below to brown or yellowish-red above is apparently an effect of weathering, the water that caused the change passing along some of the more sandy laminæ, producing red bands in the blue and often broad rusty belts, or concretionary forms, some of the last being two and three feet in diameter, and oval or globular. Such hardened and stained parts simulate logs and woody fibre, representing annual growths about a central pith. They usually accompany the stratification, but sometimes they swell out into the more clayey strata and produce a banded coloration that crosses the laminæ so as to confuse the structure, and even to cause it to appear to take a different direction suddenly in a manner of "false bedding." On close inspection, however, it can be seen that this is little more than a coloration due to creeping of iron stain into the clay, and that the real stratification laminæ ran on through it without deflection. In some cases, still, the staining process has caused a hardening coincident with the staining bands. This then is also followed, on washed surfaces, by a projection of the oxidized hardened forms beyond the other less changed parts, which adds to the deceptive appearance. Even here the lines of the original strata are traceable diagonally through the hardened portion, proving there was no original irregularity in the sedimentation.

This laminated clay, when blue, makes cream-colored brick. But the top is changed chemically so as to make a red brick. In the upper 10 or 15 feet the lime is separated from the iron and is seen in the form of limy concretions (plate C), while the iron is a peroxide, producing the general ochery and cherry-red stains. The protoxide condition of the iron below 10 or 15 feet seems to ally this clay to that blue clay seen at Minneapolis and Chaska, which has been attributed to the intermixture of Cretaceous elements, this being another indication that Cretaceous strata once covered this region.

This clay extends generally under the flat region. It is about 300 feet above the flat on which Superior city is located. The Wrenshall station is 1,044 feet above tide, and when Nemadji lake outflowed by way of Moose lake the water at Wrenshall had a depth of about 25 feet.

The strata in this clay are sometimes disturbed and crumpled, somewhat like the brick clay seen above Minneapolis in the Mississippi valley,† and at Coon creek in Anoka county. This crumpling has been attributed to later glacial action, but it is not supposed that glaciers returned over the Nemadji valley after the formation of this clay. There may have been, however, such fluctuations in the Nemadji glacier that after the laminated clay was formed it was crowded and crumpled over wide belts but not entirely disrupted and destroyed.

Kames. There are several long, narrow, drift ridges largely composed of gravel, in the county. One runs through sections 22 and 23, township 48, range 18, in a direction about southeast; one on section 26, township 49, range 17, bears nearly south; those on sections 8 and 9, township 47, range 17, run about southwest. There are a

*Similar phenomena are seen in the lacustrine clay about the west end of lake Erie, as described by the writer 25 years ago in the Ohio reports.

†Volume ii, of this report, p. 360, fig. 22.

number of ridges of similar character running southwestwardly in the western part of the Nemadji valley, and they appear to mark the points of exit of large glacial streams from the Superior basin into the valley southwestward, when the ice covered the most of the Nemadji valley.

There are several interesting localities that should receive further examination and study, viz.:

Sections 1 and 2, township 47, range 18, when the northeastern end of the abandoned channel has been filled with sand and gravel probably by the later stream following the Blackhoof valley: the kame, plateau and channels between Carlton and Cloquet, sections 23, 25, 26 and 27, township 48, range 18; the numerous sand and gravel ridges in sections 2, 3, 8, 9 and 10, township 48, range 17; the rounded hills whose hight is about 1,200 feet, on sections 7, 17 and 18, township 48, range 16; and on section 12, township 48, range 17; the gravel banks lodged on the west side of the rocks in section 10, township 48, range 17; and on the east side of the rocks near the Northern Pacific railroad, in section 7, township 48, range 16; the channel through township 47, range 18, with its east end dammed by sand and gravel, from the later streams on section 12, township 47, range 18; the evidence of post-glacial wash all along the valley from Carlton to Moose lake; the banks of the Blackhoof and Nemadji rivers from section 9, township 47, range 17, to the state boundary and eastward; the terrace and other features and the channel bank east of the Blackhoof through section 31, township 48, range 17, and sections 6, 7 and 18, township 47, range 17.

Springs are numerous throughout the county except in the flat lands of the western part. They are found in the banks of nearly every stream, and often upon the lake shores and at the foot of gravel hills. A few are so large as to form streams at once several feet in width. Such are:

(1) Near the northwest corner of section 26, township 49, range 17.
(2) Near the northwest corner of section 30, township 48, range 17.
(3) On sections 14, 15 and 21, township 48, range 16.
(4) On section 33, township 46, range 17.
(5) On section 12, township 47, range 18.
(6) On N. W. ¼ N. W. ¼ section 27, township 46, range 18.
(7) On N. E. ¼ S. W.¼, section 22, township 46, range 18.

And doubtless many exist that have not been discovered.

A small sulphur spring, leaving a white deposit on the rocks and giving off sulphuretted hydrogen, was noticed near the water in the north bank of the St. Louis river, in a crevice of the sandstone rocks near the east line of section 1, township 48, range 16. The sulphur of this spring was thought to be derived from the decomposition of some of the abundant pyrite in the conglomerates near by.

Chalybeate springs are quite common. They are often derived from the drainage through the gravel of the water of some muskeg. This is well shown in the banks of Rusty brook, a small tributary of Hasty brook, on section 5, township 49, range 20. A short distance south of this spring is an extensive muskeg separated from the brook by a low, sandy ridge. The water of the brook has a most repulsive appearance, flowing over its abundant ocherous deposits. It has a strong inky taste, and has attracted many visitors in the hope of finding iron ore. The organic acids derived from the muskeg cause the precipitation from the water of the iron it contains, and it appears as sesquioxide at the springs based on it as a reservoir. In some localities quite extensive deposits of ochre or "paint rock," and of bog ore are thus formed.

Economic resources. Several attempts have been made to make roofing slate of the slates in the valley of the St. Louis river, but thus far they have not been fruitful. The material is rather hard and brittle, and too much intersected by seams. It may be, however, that some more pliable portions may be used. There is a large exposure of softer slate on the left bank of the St Louis river, about half a mile above the crossing of the Duluth and Winnipeg railroad, and in general where the quartzose conglomerate lies on these slates they are more soft, but in general also more sectile and suitable for pencils.

The clay which covers the Nemadji basin is excellent for brick, of which it makes a light, cream-colored article, which is constantly becoming known for its excellence, and is sent to distant points. This country is covered, fortunately, with a forest of sufficient volume to supply the needed fuel for many years. This forest has already supplied a large amount of white pine, and contains still much more. Brick have also been made at Barnum by Mr. Wm. Oliver and others.

In this county there has been considerable "prospecting" for gold and silver. The numerous veins of pyritiferous quartz have tempted many to expense in shallow shafting. Some of these localities are as follows:

N. E. ¼ N. E. ¼ section 36, township 49, range 16.
Section 6, township 48, range 16.
Section 16, township 48, range 16.
Section 32, township 46, range 20 (west bank of the river).
Section 4, township 45, range 20 (east bank of the river).
Sections 4, 5 and 8, township 47, range 18.
N. W. ¼ section 2, township 48, range 16.
Section 10, township 48, range 16 (on the islands).
N. W. ¼ section 16, township 46, range 20.

The vein of graphite, reported by Schoolcraft at the end of the Knife falls portage, remains undeveloped. Yet there has been some excavation on a graphitic quartzose vein near the river, on the east side, on N. E. ¼ N. E. ¼ section 31, lot 1, township 49, range 16. This mineral is quite common in small quantities, often associated with calcite. At the working on section 31, the vein in which graphite is found is about 12 inches wide, and the excavation is about 20 feet deep. The vein itself is of quartz, cutting the slates, and has much disseminated plumbaginous matter, but has no promise of economic value.

Nuggets of metallic copper. In the digging of the well of Dr. Thomas, at Moose Lake, a piece of copper was found that is said to have weighed about 50 pounds. According to Frank Cole, formerly engineer of the St. Paul and Duluth railroad, many pieces of native copper were found in the drift in grading the railroad from Carlton to Cloquet, the aggregate being nearly or quite a ton. There were many hundred pieces. It lay in the clay, or at the foot of the clay bluffs where the grade approaches them at about three miles north from Carlton, and among gravel and stones that constitute the paved surface over which the St. Louis river formerly ran, all the way from Carlton.

At Otter Creek Station, according to Mr. H. M. Waldorf, a piece weighing several hundred pounds was found in the gravel pit.

For general agriculture the county is almost unknown, but it is capable of extended cultivation. There are a few good farms, and the county is destined to have many more. About Mahtowa, and southeastward from Barnum, are some attractive farming locations.

Note. Mr. S. J. Basye is authority for the following: He exhibited a red, hard cupriferous conglomerate mass which he stated was obtained on section 30, township 46, range 18. According to his description it occurs in a ravine, largely under water, extending 12 or 16 feet. It rises into a small bluff further east, but has not been seen by any member of the survey. The pebbles in this conglomerate are quartz-porphyry, felsyte or fine granite.

Note of rock outcrops in Pine county. Since the report on Pine county was published (vol. ii), several localities have been noted of rock outcrops not mentioned in that report, but visited by Mr. Ayres, viz.:

Section 29, township 44, range 21, in the N. W. ¼, near the north line of the section, a red granitic rock occurs. It is but slightly exposed on a gentle eastward slope, with numerous boulders of the same material.

Section 30, township 44, range 21, S. E. ¼ of the S. E. ¼, a similar rock appears having a slight exposure.

In the northeastern corner of section 25, township 45, range 17, along the valley of a creek flowing westward, and also forming outcrops on the north and south sides of the creek, is a greenish diabasic rock, somewhat porphyritic, possessing some of the lithological features of the rocks at Duluth and eastward, and at the dalles of the St. Croix at Taylor's Falls. In the vicinity are numerous angular blocks of buff sandstone which also probably underlies the immediate vicinity.

On Pine river, S. E. ¼ S. E. ¼ section 20, township 44, range 21, sandstone occurs in outcrop. It is mostly below the level of high water, the strata being horizontal and thin-bedded.

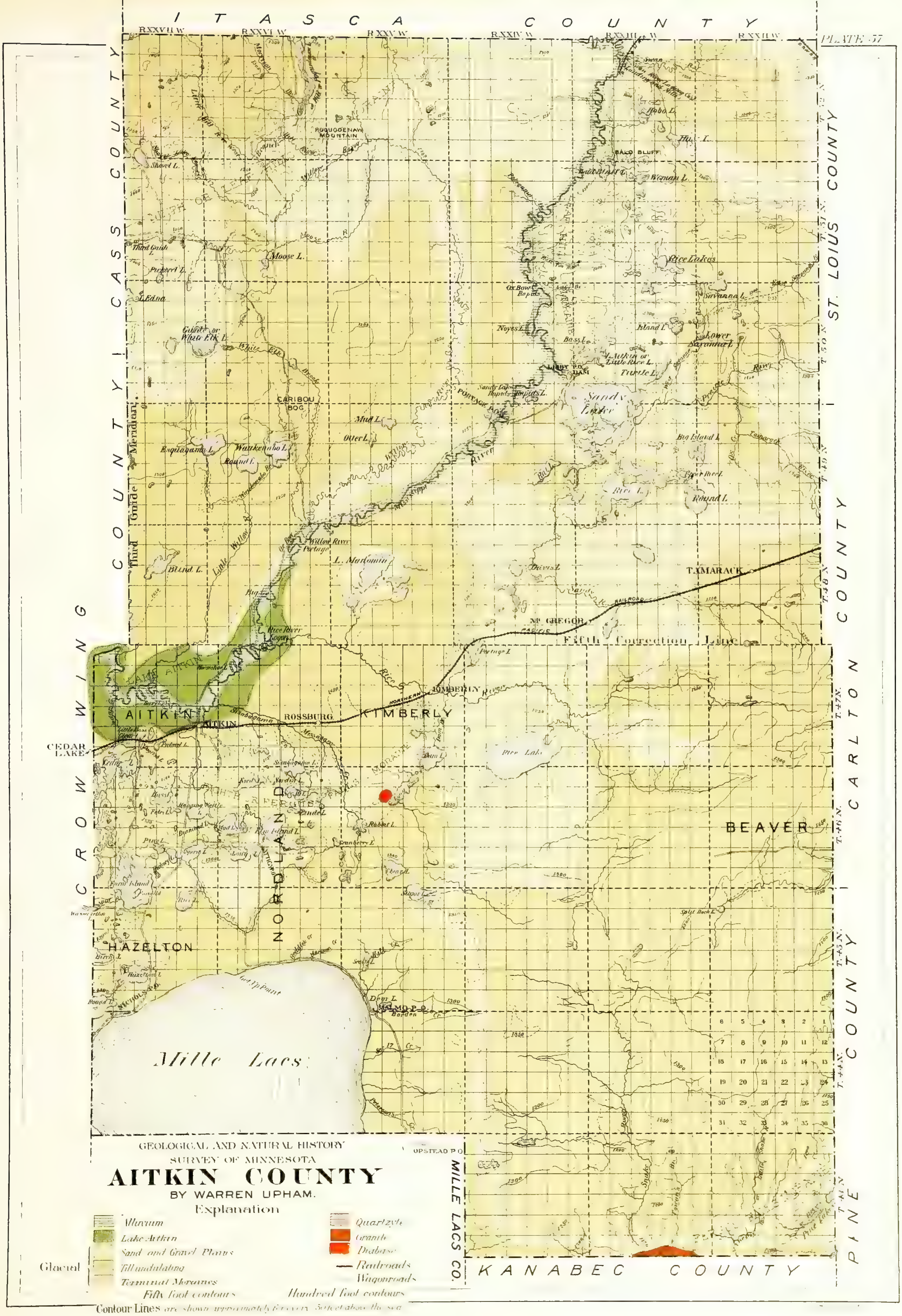
On a branch of Willow river, section 1, township 44, range 19, the Hinckley sandstone extends half a mile, rising ten feet along the river.

Rock samples collected in Carlton county. Nos. 443-510; 1607-1614; 1969-1975; 1977-1979; 2079-2091.

Series of A. H. Elftman. Nos. 264, 265.

Series of J. E. Spurr. No. 187.

PLATE 57



ITASCA COUNTY
CASS COUNTY
CROW WING COUNTY
ST. LOUIS COUNTY
CARLTON COUNTY
PINE COUNTY
KANABEC COUNTY
MILLE LACS CO.
Third Guide Meridian
Fifth Correction Line
AITKIN
KIMBERLY
BEAVER
HAZELTON
NORDLAND
CEDAR LAKE
ROSSBURG
TAMARACK
MC GREGOR
BALD BLUFF
CARIBOU BOG
POQUODENAW MOUNTAIN
Sandy Lake
Mille Lacs
Lake Aitkin
Rice Lake
UPSTEAD P.O.
GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA
AITKIN COUNTY
BY WARREN UPHAM.
Explanation
Alluvium
Lake Aitkin
Sand and Gravel Plains
Glacial
Till undulating
Terminal Moraines
Quartzyte
Granite
Diabase
Railroads
Wagonroads
Fifty foot contours
Hundred foot contours
Contour Lines are shown approximately for every 50 feet above the sea

CHAPTER II.

THE GEOLOGY OF AITKIN COUNTY.

By WARREN UPHAM.

Situation and area. Aitkin county (plate 57) lies in the northeastern part of the interior of Minnesota, about midway between lake Itasca and the west end of lake Superior. The Mississippi river flows through its northern and western portion, and the town of Aitkin, which is the county seat and most important centre of population, is situated near the south bank of this river, lying on both sides of its tributary, the Mud river, at a distance of five miles east from the west boundary of the county.

Measured by straight lines, the distances from Aitkin in three directions to the chief commercial cities of Minnesota and its borders are the following: to Saint Paul and Minneapolis, slightly east of south, about 110 miles; to Duluth and West Superior, slightly north of east, eighty miles; and to Moorhead and Fargo, a little to the north of west, 150 miles.

Excepting a deficiency of three townships which mostly lie in the southern part of the large lake called Mille Lacs and belong to the county of that name, Aitkin county forms a rectangle. Its length from south to north is ten townships (43 to 52 north from the parallel forming the south line of Wisconsin), or sixty miles. Its width south of the Mississippi is six ranges (22 to 27 west from the fifth principal meridian), or thirty-six miles. North of this river, where the third guide meridian is the west boundary, the townships of range 27 lack about two miles, and that part of the county has a width of about thirty-four miles.

The area of Aitkin county is 1,994.97 square miles, or 1,276,782.38 acres, of which 111,090.48 acres are covered by water.

SURFACE FEATURES.

Natural drainage. This county lies chiefly within the drainage basin of the upper Mississippi river. Outside that basin an area of about 300 square miles, on the southeast, is drained by streams flowing to the Kettle river and by the upper part of the Snake river, which are tributaries of the St. Croix and thereby send their waters into the Mississippi; and, at the southwest, a land area a few miles wide adjoining Mille Lacs is tributary to that lake and to Rum river.

From the west the Mississippi receives in Aitkin county, in their order from northeast to southwest, the Willow river, the White Elk brook, and the Little Willow river. The drainage areas of the two latter are comprised wholly in this county; but the Willow river basin extends considerably beyond the county lines on the north and west, and includes among its farthest sources many lakes and lakelets in Cass county. The Hill and Moose rivers are tributaries of the Willow and supply to it large portions of its annual log-drives. From the east and south the affluents of the Mississippi in this county are the Swan river, whose basin lies mostly in Itasca county; Sandy river, flowing through Sandy lake, which also receives the waters of the Prairie river and of its branches, the West Savanna (or Savanne) and Tamarack rivers, the sources of the Prairie and the Tamarack being in St. Louis and Carlton counties; the Rice river, and Sisabagama or Missagony creek, each lying wholly in Aitkin county; and the Mud river and Cedar creek, together draining a region of many lakes and receiving their head streams from Crow Wing county.

The Mississippi here flows in a general south and southwest direction, but has almost countless meandering curves that carry it alternately a half mile, more or less, to each side of the central course. Its low alluvial belt of fine silt formed by deposition from the river floods is thus crossed many times by the stream, and the basal portions of some of its curves have been brought very close together by the erosion of the river banks. Such curves, usually called "ox-bows," require the steamboat and log-drives to pass in some places around a distance of one to two miles, where a canoe or light boat with its contents is quickly transferred by a portage across the intervening neck of land, which occasionally is only a few rods wide. At ordinary stages of low water, and far more during the highest floods, the current is continually wearing away the upstream side of the portage isthmus, until at last the base of the river's loop is cut entirely across. The stream then takes the slightly more inclined and straighter course where the portage formerly was, and the ends of the old channel loop become gradually filled up with alluvial silt.

Lakes. Numerous long and narrow, often horseshoe-shaped lakes, formed in the manner described by the foregoing paragraph, lie in abandoned parts of the ancient channels of the Mississippi. For these lakes of the alluvial land adjoining the river the name "logans" has been in common use in Aitkin county and along other parts of the upper Mississippi during the twenty-five years or more since the region was first invaded by lumbermen. In New England such lakes are called "moats," and this term is recommended by Prof. N. S. Shaler for general use by geologists in describing lakes of this class.*

Examples of these lakes are the Berry logan, on the south side of the Missis-

*U. S. Geol. Survey, Tenth Annual Report, for 1888-'89, pp. 276-278, with a map of typical "ox-bow cut-offs" or *moats* of the lower Mississippi river.

sippi two miles northwest of Aitkin; the Horseshoe logan, in the S. E. ¼ of sec. 6 and the N. E. ¼ of sec. 7, T. 47–26, on the northwest side of the Mississippi about four miles from Aitkin on the road to Willow river and Sandy lake; the Rice River logan, crossed by the north line of sec. 4 of this township, lying east of the Mississippi and close north of the mouth of Rice river, formerly used as a reservoir for logs; and the Big logan, as it is known to lumbermen, west of the Mississippi in the east part of sec. 21, T. 48–26, two and a half miles north of the last.

About a mile west from the mouth of the Rice river, a portage named from that stream crosses an extremely narrow isthmus, now only about one rod in width at the top of the steep banks of the Mississippi, where at no distant time a new logan will doubtless be formed, being left on the south side of the shortened river course. Two other very short portages are made across the necks of ox-bow peninsulas about a mile south and a like distance east of Mr. L. G. Seavey's ranch, which is situated on the Willow river at the bridge of the Aitkin and Sandy Lake road, the former being known as the Willow River portage, and the latter as the Sioux portage. Probably ere long in each of these places the river will leave the looped parts of its channel to become logans.

Among the drift-enclosed lakes of Minnesota,* the next to the largest, exceeded only by Red lake, is Mille Lacs, having an area of about 200 square miles, of which the northern half, approximately, is comprised in Aitkin county. The extreme fluctuation of the level of this lake is four or five feet. A careful measurement on the township plats shows that the entire area enclosed within the watershed of Mille Lacs is 400 square miles, very nearly, and that the lake itself occupies almost exactly half of this area. The farthest rainfall draining into the lake is only five or six miles distant from its shores, and for an extent of several miles along the middle part of its north side the width of the land whose waters are tributary to the lake is no more than one to one and a half miles. Perhaps no other lake in the United States, having so large size and situated like this at the head of an important river, bears so large a proportion to its drainage basin.

The depth of Mille Lacs, according to soundings by Mr. F. B. Sumner, assistant with Prof. H. F. Nachtrieb and Dr. Albert Schneider in their investigations of the lacustrine fauna of this district during the year 1892, and by Mr. Robbins, a former Indian agent now living near the southwest shore, appears to range mainly from twenty to fifty feet, and its maximum is reported to be eighty-four feet. Near the shores the water is very shallow. In many places a man may wade out a quarter of a mile, and probably the average depth at a mile from the shore is no more than twenty or twenty-five feet.

*For a classification of the lakes of Minnesota, see vol. i, p. 130.

During storms and any time of high winds raising considerable waves, the water of this lake, to a distance varying mostly from fifty to a hundred rods or farther off shore is roiled and turbid with very fine sand and mud held in suspension, while at a greater distance out in the lake the water is seen to be still clear, with a very noticeable contrast of color between the turbid and clear portions. To this roiled condition of the shallow water I attribute the remarkable and frequent mortality which causes many fish, mostly species of pike or pickerel, perch, and tullibee, to die and float ashore. These ill-fated individuals, of whom hundreds may sometimes be counted along a few miles of the lake beach, I suppose to have become bewildered in the sandy and muddy water and to have remained so long in it that death resulted from injury to their delicate gills or from a film gathering there and producing suffocation.

The southern half of Mille Lacs comprises about a dozen islands, mostly near the shore. Several of them consist chiefly of wave-washed boulders, but others of larger size have a soil of till or boulder-clay and are wooded. Two stand far out in the lake, three or four miles from the nearest shore and from each other, namely, Prisoner's island on the east, so called from some tradition of Hennepin's enforced stay here in the year 1680 with the Sioux Indians, and Spirit island, on the west. The latter, some thirty feet high, is the highest island in the lake. It is reported to consist of an outcrop of the bed rock and to receive its name from the superstitious dread or awe with which it is regarded by the Chippewas or Ojibways who vanquished and drove away the Sioux, and now occupy the reservation bordering the south part of the lake in Mille Lacs county.

Of the 220 other lakes and lakelets shown by the government plats of Aitkin county, Sandy lake (figure 2) is the first in size and also is the most interesting in the geologic and topographic features of its shores, long projecting peninsulas, and several islands, composed of the glacial and modified drift, and in its associations with the history of discovery and early exploration in this region, when, for nearly a hundred and fifty years, the Canadian voyageurs, fur traders and pioneer missionaries were its only white travelers and inhabitants. After passing from Montreal along the Great Lakes to the head of lake Superior, the voyageurs ascended the St. Louis river about fifty miles to its most western bend, where it is less than twenty-five miles distant from the Mississippi at the mouth of Sandy lake and river. This intervening tract was crossed by ascending the East Savanna river to its sources in a large swampy meadow or savanna, through which, for the final mile or more, an artificial canal was made, portaging thence about three miles to the West Savanna river in sec. 7, T. 50–22, and descending the latter stream to Prairie river, Sandy lake and the Mississippi. Along this route, during more

than a century, supplies were brought for the trading posts of the Hudson's Bay Company on the upper Mississippi and throughout a very large area farther northwest; and the returning canoes, coming back over the same route, were laden with rich furs destined for Montreal and the more distant markets of England and continental Europe. Cellar holes are still pointed out on the narrow tract of gravel and sand between the Mississippi and the last quarter of a mile of the Sandy river,

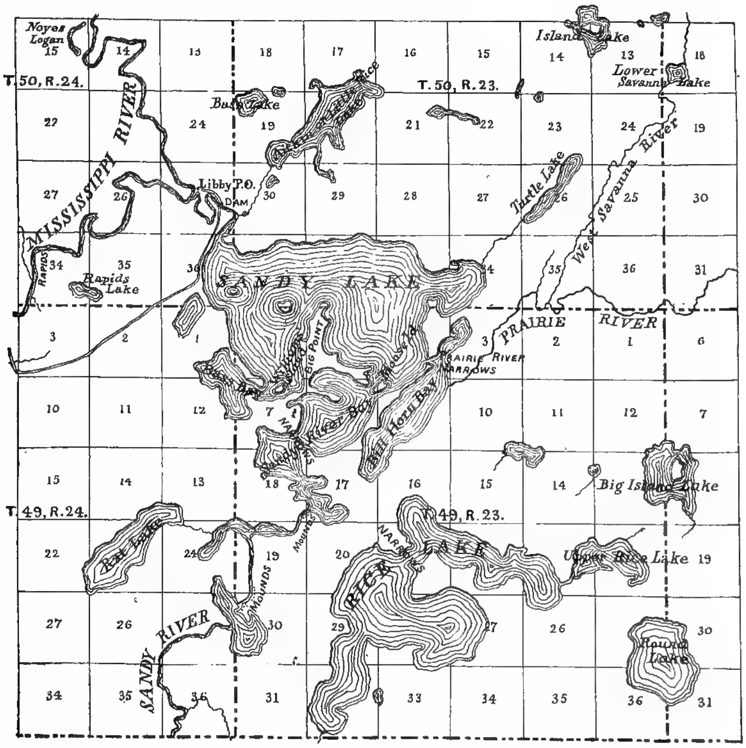


FIG. 2. SANDY LAKE AND ITS VICINITY.

marking the sites of former trading posts of the Hudson's Bay, Northwestern, and American fur companies. The only permanent lodges of Indians remaining in Aitkin county are twenty or more in this vicinity, within the distance of a mile southeastward to the mouth of Sandy lake.

A dam on the Sandy river nearly midway between its mouth and this lake is now being built by the United States government, as a part of the reservoir system of the upper Mississippi for increasing the flow along the lower portion of the river during its low stages. According to the surveys for this work, the drainage basin of Sandy lake has an area of 385 square miles; and the area of the lake at its ordinary low stage is 8.91* square miles, or approximately 5,700 acres, its ratio to the drainage area being 1.43,* nearly. The dam will have a vertical storage capacity of fifteen feet, but only two-thirds of this will be used, as it is not intended to flow the lake at any time more than ten feet from its lowest stage. Above this flowage level, the

* According to my measurement on township plats.

dam will shut out the highest floods of the Mississippi, which rarely have risen, as in the spring of 1888, to a hight of fourteen feet. Levelling by the United States engineers determines the hight of the Mississippi here as 1,210 feet above the sea, and of Sandy lake about five inches more, each being taken at the extreme stage of low water. The depth of Sandy lake has not been ascertained by sounding, but is thought to range from ten to twenty-five feet in the central and wider portions.

Rice river receives the outflow of nine lakes ranging from one to four miles in length, namely, Rice lake, so named for its crops of wild rice (*Zizania aquatica*); Long and Dam lakes, the latter name referring to the low, ice-formed ridges of gravel and sand on its shores, especially at its mouth; Portage lake, a few miles east of Kimberly, bordered by picturesque morainic hills; and Manomin (meaning wild rice) lake, with four others, in T. 48-25.

Clear and Rabbit lakes, exceptionally beautiful, with very clear water and enclosed by high shores, the latter having several peninsulas and one or more islands, lie in the southwest part of T. 46-25. Rabbit lake and five or six pretty lakes and lakelets in the north part of T. 46-26, including Ten lake (so named from its being mainly in sec. 10), Sisabagama, Nordin, and Nord lakes, are tributary, either by outlet streams or by outflow through swamps or through the porous drift deposits, to the Sisabagama or Missagony creek.

Next in order westward, the Mud river receives tributary waters from nearly half a hundred lakes and lakelets. Its most remote sources are a series of lakes, through several of which it flows, in T. 45-28, Crow Wing county. In its further course, lying in this county, the Mud river flows through Farm Island lake, about three miles long and two miles wide; Pine, Hickory, and Spirit lakes, situated in a closely connected series joined to each other and to Farm Island lake by short tracts of stream having a gentle current and only very slight fall; and Elm Island, Mud, Diamond and Hanging Kettle lakes, ranging, except the third, which is the smallest, from one and a half miles to one mile in length, joined like the foregoing, in another series of only slightly decreasing hight. Rice lake, in sec. 2, Hazelton, and Bass lake, in sec. 10, T. 46-27, outflow by short streams to the Mud river. The former of these, like numerous other lakes throughout this region, is named from its wild rice, and the latter from its black bass fishing, in which its reputation surpasses the dozens of other lakes of this county in which the same fish abounds. Lone lake, lying a half mile south of Elm Island and Mud lakes and about forty-five feet higher, bordered on the north and east by a level sand and gravel plain ten to fifteen feet above its surface, has no visible outlet; but it probably supplies the water of large chalybeate springs which issue close south of the road, near the middle of the south side of Mud lake. The maximum depth of Lone lake, in its narrows, is reported to be sixty feet.

Cedar lake, about four miles long, and of remarkably irregular outlines, named from the red cedars which in scanty numbers are found on its hilly shores and islands, presents very attractive fishing. It outflows to the Mississippi by the Cedar creek, whose head stream in Deerwood township, Crow Wing county, flows from Hamlet and Portage lakes.

The two most considerable lakes in Aitkin county tributary to Mille Lacs are Hazelton or Echo lake and Round lake, in the southwest part of Hazelton township, each nearly two miles long and surrounded by mostly high shores. Eagle island, in Hazelton lake, on which a pair of eagles have nested during several recent years, is separated from the northwest shore, there a projecting low gravel and sand ridge of modern ice accumulation, by only a very narrow strait. Soundings of these lakes by Mr. F. B. Sumner, gave for Hazelton lake a maximum depth of thirty-six feet, and for Round lake ninety-one feet; the latter being found deeper than any other one of many lakes sounded in southwestern Aitkin county. The outlet from Hazelton and Round lakes to Mille Lacs flows through Borden lake in Crow Wing county, which, according to Mr. Sumner, has several islands and a maximum depth of forty-two feet.

The southeastern quarter or third part of Aitkin county has few lakes, the most worthy of mention being the long and narrow northeastwardly trending Pine lakes, in the east edge of the most southeastern township of this county.

Northwest of the Mississippi several notable lakes lie in this district, as Blind lake, about two miles long in the north part of the fractional T. 48-27, mainly enclosed by a large swamp, and having no outlet as is implied by its name; Esquagemaw, or Little Willow, and Waukenabo lakes, outflowing respectively by the west and east forks of the Little Willow river; Round lake; White Elk or Guide lake, at the head of the White Elk brook; Shovel lake, tributary by a very short outlet to the Willow river and Hill or Poquodenaw lake, four miles long and averaging a third of a mile wide, outflowing by the Hill river into the Willow. East from the meridian of Waukenabo and Poquodenaw lakes to the Mississippi is a prevailingly swampy tract of four or five townships which have few or no lakes.

When this county shall have become generally occupied by farms, which quite surely within the next century will displace the forest and open wide views across extensive cultivated and pastured fields, its plentiful lakes will be much prized for their utility and for their elements of beauty and diversity in the landscape.

Topography. The greater part of Aitkin county has a nearly level or only moderately undulating or rolling surface; but some portions are occupied by morainic

drift hills which usually are twenty-five to seventy-five feet high and rarely rise 100 to 250 feet above the adjoining streams and lakes. The least altitudes in this area are on the southeast and west, where the Snake river, branches of the Kettle river, and the Mississippi, cross the county boundaries; and the highest point is the Poquodenaw "mountain," as it is commonly called, in allusion to which the Hill river and lake receive their names, situated in sec. 25, T. 52-26, not quite five miles south of the north line of the county. From the lowest lands on the streams mentioned, about 1,150 feet at the southeast, and 1,185 feet at the west, above the sea, to the top of Poquodenaw, estimated 1,525 feet above the same level, there is a vertical range of less than 400 feet.

Along the northern and eastern shores of Mille Lacs no tracts higher than twenty to thirty feet above the lake are visible. A few miles distant from this lake, its watershed, gently undulating and often swampy on the east and northeast, but in part formed of hilly morainic drift on the northwest, rises 50 to 100 feet above the lake or 1,300 to 1,350 feet above the sea. From this watershed the country tributary to the St. Croix river has a slight general slope toward the southeast, sinking along the water courses to about 1,150 feet above the sea on the southern and eastern lines of Aitkin county. Toward the north, in the drainage area of the Mississippi, a rather hilly contour extends nearly to Aitkin.

Northeastward from the Mille Lacs watershed, a somewhat hilly belt extends past Kimberly and Portage lake to Sandy lake and thence northerly along the east side of the Mississippi to Bald bluff and Hobo lake in T. 52-23, a few miles south of the mouth of Swan river and the north line of Aitkin county. Farther east, the watershed dividing the Mississippi basin from that of the Kettle river and from the East Savanna and Floodwood rivers has no conspicuous elevations, and consists in many places of swamps. Its average hight is about 1,300 feet above the sea, being no more than 100 feet above the Mississippi, from which it is ten to twenty-five miles distant, except where it extends into Carlton and St. Louis counties in passing around the headwaters of the Prairie river.

The Mississippi has accomplished little erosion along all its course in this county; but instead, having begun to flow in the lowest depression of the drift-covered surface at the close of the Ice age, generally bordered by very gentle slopes on each side, it has covered the bottom of this broad and shallow valley with a level plain of alluvium, usually a half mile to one mile wide.

Northwestward the original surface of the drift, ascending very slowly from the alluvial belt, is often so flat or somewhat depressed on considerable tracts that they have become mantled by shallow, peaty swamps. Ten to twenty miles from the Mississippi, however, morainic hills are again found, mostly low and seldom com-

manding any extensive veiw in this wholly wooded region, but culminating at the north in the Poquodenaw hill or "mountain." Though this hill has an elevation only about 250 feet above the lakes and rivers near its base, it is conspicuously higher than the low hills and undulations of its neighborhood, and overlooks a wide and beautiful prospect of far-stretching forest, dotted here and there with lakes and with very rare cleared and cultivated spots adjoining the lumbermen's camps.

Elevations, Northern Pacific railroad.

From profiles in the office of S. D. Mason, engineer, and Richard Relf, assistant engineer, St. Paul.

	Miles from Duluth.*	Feet above the sea.
Tamarack (formerly Sicotte's) station,	61.6	1,271
Hay river, bed, 1,228; grade,	65.7	1,238
Summit, natural surface,	66.3	1,244
Hay river, second crossing, bed, 1,222; grade,	67.5	1,232
Sandy river, bed, 1,219; grade,	68.8	1,228
McGregor,	70.7	1,228
Portage lake, grade,	75.9	1,220
Summit, natural surface,	77.4	1,266
Kimberly,	79.6	1,237
Rice river, bed, 1,209; water, 1,213; grade,	80.0	1,226
Summit, natural surface,	84.3	1,254
Rossburg,	85.4	1,222
Sisabagama creek, bed, 1,206; grade,	87.0	1,214
Summit, natural surface,	88.8	1,241
Mud river, bed, 1,191; water, 1,193; grade,	91.3	1,205
Aitkin,	91.5	1,208
Outlet of Pickerel lake, bed, 1,208; lake, 1,210; grade,	93.2	1,215
Little Bass, Dogfish, and Clear lakes, passed in next mile west,	93.5–94.0	1,206–1,204
Summit, natural surface,	93.7	1,224
Cedar creek, bed, 1,199; water, 1,200; grade,	95.1	1,212
Cedar lake, water at ordinary low stage,	95.1	1,201
Cedar lake station,	96.3	1,222

Duluth, Mississippi River & Northern railroad. (Great Northern.)

From profile in the office of the Swan River Logging Company.

	Miles from Swan River Mills.	Feet above the sea.
Swan River Logging Co.'s mills and landing,	0.0	1,242
Swan river, near its mouth, water, 1,226; grade,	0.4	1,241
Summit level, cutting 5 feet; grade,	2.1–3.0	1,271
Swan river, second crossing, water, 1,252; grade,	3.5	1,261
Swan River station, crossing the Duluth & Winnipeg railroad,	6.7	1,293

Duluth & Winnipeg railroad. (Great Northern.)

From profile in the office of Alex. Stewart, engineer, Duluth.

In the northeastern corner of Aitkin county this railroad, passing diagonally across sec. 1, T. 52–22, has an elevation of 1,260 feet, this being in a large swamp, partly bearing tamarack and spruce, and partly an open bog, through which ditches have been cut to carry off the surplus water in spring to the Floodwood river.

Mississippi river, Sandy lake, and Mille Lacs.

From levelling by U. S. engineers, under the direction of Maj. C. J. Allen, St. Paul; and from the foregoing railroad surveys.

	Feet above the sea.
Mouth of Split Hand creek, ordinary low stage,	1,236
Mouth of Swan river, ordinary low stage,	1,226

*Distances are by the new line of this railroad, passing through West Superior to Carlton, being 4.5 miles greater than by the St. Paul & Duluth railroad line, which was formerly used by this company.

	Feet above the sea.
Mouth of Sandy river, low and high water,	1,210–1,224
Sandy lake lowest stage,	1,210.4
Level of proposed reservoir flowage of Sandy lake,	1,220
Top of Sandy lake dam,	1,225
Mississippi river at Aitkin, low and high water,	1,190-1,200
Mouth of Pine river, ordinary low stage,	1,177
Mille Lacs, ordinary stage, 1,251; extreme low and high water,	1,249–1,254

Other lakes in Aitkin county.

Approximate estimates of the elevations of other lakes in this county are as follows:

	Feet above the sea.
Tributary to the Willow river—	
Hill or Poquodenaw lake,	1,260
Shovel lake,	1,300
Tributary to the White Elk creek—	
White Elk or Guide lake,	1,290
Tributary to Little Willow river—	
Esquagemaw and Waukenabo lakes,	1,250
Tributary to the Rice river—	
Rice lake,	1,230
Dam lake,	1,240
Long lake,	1,250
Portage lake,	1,216
Lake Manomin,	1,210
Tributary to Mud river	
Farm Island, Pine, Hickory and Spirit lakes,	1,255–1,250
Elm Island, Mud, Diamond and Hanging Kettle lakes,	1,210–1,205
Lone lake,	1,250
Tributary to Cedar creek—	
Cedar lake,	1,201
Tributary to Mille Lacs—	
Round lake,	1,260
Hazelton or Echo lake,	1,265
Tributary to Pine and Kettle rivers—	
Pine lakes, in the southeast corner of the county,	1,140

Estimates of the average hights of the townships of Aitkin county, based on the contour lines of plate 57, are as follows: T. 52–22, 1,265 feet above the sea; T. 51–22, 1,285; T. 50–22, 1,285; T. 49–22, 1,275; T. 48–22, 1,280; T. 47–22, 1,310; T. 46–22 (Beaver), 1,275; T. 45–22, 1,250; T. 44–22, 1,240; T. 43–22, 1,220; T. 52–23, 1,275; T. 51–23, 1,300; T. 50–23, 1,275; T. 49–23, 1,250; T. 48–23, 1,250; T. 47–23, 1,275; T. 46–23, 1,300; T. 45–23, 1,310; T. 44–23, 1,260; T. 43–23, 1,220; T. 52–24, 1,270; T. 51–24, 1,265; T. 50–24, 1,260; T. 49–24, 1,255; T. 48–24, 1,260; T. 47-24, 1,250; T. 46–24, 1,275; T. 45–24, 1,320; T. 44–24, 1,310; T. 43–24, 1,275; T. 52–25, 1,290; T. 51–25, 1,270; T. 50–25, 1,275; T. 49–25, 1,240; T. 48–25, 1,235; T. 47-25 (Kimberly), 1,270; T. 46–25, 1,285; T. 45–25, 1,290; T. 44–25, 1,290; T. 52–26, 1,325; T. 51–26, 1,290; T. 50–26, 1,300; T. 49–26, 1,280; T. 48–26, 1,230; T. 47–26, 1,240; T. 46–26 (north half of Nordland), 1,260; T. 45–26 (south half of Nordland), 1,255; T. 44-26 (wholly in Mille Lacs), 1,251; T. 52–27, 1,360; T. 51–27, 1,375; T. 50–27, 1,350; T. 49-27, 1,310; T. 48–27, 1,250; T. 47–27 (Aitkin), 1,220; T. 46–27, 1,265; T. 45–27 (Hazelton), 1,280; and T. 44-27 (mostly in Mille Lacs, with land in portions of secs. 4 to 7, forming the southwest corner of Hazelton township), 1,252.

From these estimates the mean elevation of the county is found to be 1,273 feet, but perhaps it may better be stated in round numbers as 1,275 feet, above mean sea level.

Soil and timber. If, with the plentiful lakes and streams of Aitkin county, we exclude also, as uncultivatable, its frequent swamps and bogs, covering perhaps a quarter or third of its whole land area, nearly all the remaining surface possesses a rich and durable soil, well adapted for agriculture. Since the Northern Pacific railroad was built through this county in 1871, an experience of more than twenty years in farming has shown that all crops and all farm stock properly belonging to this latitude can be successfully raised here. Up to the present time the leading busi-

ness interests have been those of lumber production, but in the near future the fertile lands of all portions of this county will undoubtedly attract a large immigration of permanent settlers who will clear farms, build good roads, and found villages and schools in every township.

The areas of till have everywhere a very productive dark soil, a foot or more in depth, in which the proportion of boulders and gravel is usually not so great as to hinder plowing. This soil is readily permeable to rains, and in dry seasons gradually yields its moisture to growing crops, so that they are rarely or never harmed by the moderate droughts which occasionally occur in summer. Gentle slopes and good natural drainage generally permit early sowing and planting, and the season of growth between the latest frosts of spring and the first in autum is usually about four months, permitting a great variety of farm crops to be well matured and ripened. Only small parts of the till areas, consisting of morainic ridges and hills, have too abundant boulders and too steep slopes to be available for cultivation; and these tracts, when cleared, are suitable for pasturage. Hay is a natural product of the district, for portions of many of the streams are bordered by moist lands, from a few rods to a half-mile in width, bearing a luxuriant growth of tall meadow grasses which make one to two tons or more of hay per acre. All other parts of the county are more or less wooded, and it has no tracts of open dry prairie. Many of the swamps now enclosed by higher ground are capable of drainage by ditches and will then rank as the most valuable farming land.

Somewhat less desirable generally than the foregoing are the tracts of sand and gravel called modified drift, which here usually have a black soil several inches deep, yielding well during a few years of cultivation, but afterward requiring fertilization to prevent exhaustion. No very large areas of these deposits exist in Aitkin county, which consists more largely of till than most other parts of the country traversed by the Northern Pacific railroad between Carlton and the vicinity of Frazee and Detroit in southwestern Becker county, a distance of about 175 miles.

The species of trees most valued are the white and Norway pines. The latter, though almost universally known by this name, does not occur in Norway nor in Europe, and should be more properly called the red pine, from its reddish or tan-colored bark. These trees here seldom form extensive tracts of forest, unmixed with other species; and probably no more than a quarter part of the country originally bore merchantable pine, previous to its being stripped by lumbering. Where the white pine grows in abundance and of large size, it is an unfailing sign that the soil is till, but far the greater part of the till areas are mainly or solely occupied by a hardwood forest of many deciduous species, and these also often or generally are intermingled with the white pine. Apparently the most clayey till tends to bear only

hardwood, while rather gravelly and sandy till invites the growth of white pine, and extremely sandy till, which sometimes forms portions of the moraine belts and even of the general sheet of glacial drift in this region, bears both white and Norway pines in varying proportions. Coming to a change of soil from the till to the modified drift, the white pines are usually found to be limited to the former, perhaps growing intermingled with hardwood if the land is very clayey or with the Norway or red pine if there is less clay. On the sand and gravel areas of the modified drift, especially where they are somewhat rolling or hilly, the red pine has its best development, occasionally forming stately groves. A third and smaller species of this genus, the Banksian or jack pine, which is valued for fuel and is coming to be used for frame timber but not for board-sawing, grows almost exclusively on these tracts of sand and gravel, either mixed with the red pine or alone.

The alluvial lands bordering the Mississippi bear only very rare pines, but three other coniferous and evergreen trees, namely, the spruce, balsam fir, and arbor-vitæ, the latter commonly called "white cedar," are occasionally found on such small portions of these lands as are swampy, and they often are plentiful, with tamarack, in the frequent swamps through all the county. None of these is utilized in any considerable degree as sawn lumber, but the arbor-vitæ commands a good price for use as posts and telegraph poles. Nearly all the alluvium has a dry surface, excepting when it is overflowed by the river floods due to snow-melting and rains in spring, and bears a magnificent dense forest which consists chiefly of white and red elms, basswood, sugar and silver or soft maples, and white and black ash.

On the higher tracts of till the forest comprises, besides the foregoing, the common poplar or aspen, the large-toothed and balsam poplars, canoe birch, white, bur and black oaks, ironwood, the wild plum, and black cherry. The common poplar and canoe birch are much used by immigrants for the construction of log houses. Among the rarer species of trees are the cottonwood, sometimes found along the Mississippi, and the red cedar, which occurs on the islands and shores of Farm Island and Cedar lakes.

An undergrowth of many shrubs and small trees is found throughout the woods of this region, including the common and beaked hazel-nuts, dwarfed bur and black oaks, bird cherry and choke cherry, two species of mountain ash, Juneberry, raspberry, prickly and smooth gooseberries, black currant, and several species of cornel or dogwood, of honeysuckle, and of viburnum or arrow-wood, one of the last being the bush cranberry. Prickly ash and the frost grape are somewhat frequent about Mille Lacs and northward to Sandy lake, but there attain approximately their northeastern limits. Blueberries of the dwarf or low species abound in all parts of the county, growing often in exceptional profusion where the pine woods have been cut and the refuse tops and branches burned.

GEOLOGICAL STRUCTURE.

Only three rock outcrops have been found within Aitkin county, one being quartyzte, and the other two, situated close together, exposures of a dike of diabase. The quartzyte, which may underlie a large area of the drift, seems referable to the Taconic era; but Archæan rocks probably occupy a considerable tract in the southeastern part of this county, extending thence east and south into Pine and Kanabec counties. These very ancient rocks are undoubtedly in some places, and perhaps very generally, overlain by a slight thickness of Cretaceous beds, and above all the drift is spread as a universal mantle. Descriptions of the several geologic formations are presented in the ensuing pages in the order of their age, beginning with the oldest.

Granite. Between the Snake river and Cowan's brook, in the south edge of Aitkin county, the glacial drift in the S. E. ¼ sec. 34 T. 43–23, has in some places very plentiful blocks of a fine-grained, gray granite, containing black mica. This Archæan formation is doubtless the bed-rock there at a little depth below the surface. Within a mile southwestward, and thence for nearly three miles down the Snake river, past its upper and lower falls in northern Kanabec county, Archæan granites, schists and gneiss have many and extensive outcrops.

Quartzyte. This rock forms a slightly projecting point of the northwestern shore of Dam lake, near the centre of the W. ½ sec. 35, Kimberly, T. 47–25, about three miles south from Kimberly station and eleven miles east of Aitkin. Its outcrop has a length of about 250 feet along the shore and varies in width from fifteen to fifty or sixty feet, rising to a hight of four or five feet above the lake. Through all its extent the rock is much fractured into separate boulder-like masses from one or two feet up to ten or rarely twelve feet in diameter, lying in close contact with only very scanty foreign drift boulders of granitic, trappean and other crystalline rocks such as abound in the drift of all this district and even in the immediate vicinity of the outcrop. Boulders of the quartzyte, however, are very rare in the drift, and the great abundance of its masses at this locality shows unquestionably that it is here the bed-rock, although no compact ledge is seen. The shattered condition of its whole observable extent seems probably attributable to preglacial weathering of the rock at and near this place to form low cliffs with many boulders due to gradual disintegration along crevices and joint planes. During the Glacial period some, or perhaps all, of these quartzyte masses may have been transported short distances, but the very small proportion of boulders of other rocks mingled with the quartzyte indicates that its blocks are in or near their preglacial position.

In its original condition this rock was a sandstone of well-rounded white quartz grains mostly from a thirtieth to a tenth of an inch in diameter. The spaces between the grains have become filled with similar white quartz, and the rock is now a very compact light gray quartzyte, varying rarely in superficial portions to a partially reddish color where iron peroxide coats the sand grains and stains the interstitial quartz. Some of the grains, ranging from less than one per cent. up to twenty or twenty-five per cent. have a lavender color, in which respect, and in its general lithologic aspect, this rock resembles certain portions of the Pokegama quartzyte, the formation most intimately associated with the extensive deposits of iron ore along the Mesabi range. The nearest part of that quartzyte belt lies at a distance of nearly fifty miles to the north, outcropping at the Pokegama falls of the Mississippi and stretching thence east-northeastward.

Apparently the most probable hypothesis that we can assume in attempting to correlate this Aitkin county quartzyte with the stratigraphic sequence of rock formations ascertained elsewhere in all the surrounding country, is to suppose it to be a part of some area, very probably a belt having a general east-northeast to west-southwest extension of the Pokegama formation, which is regarded as the basal member of the Taconic series. There may be, according to this hypothesis, a wide and shallow synclinal trough of the quartzyte with its northern arm resting on the southern slope of the Giant's range, and its southern rim represented by the locality here described. The dip and strike of the strata, however, were not determinable in this place, since no distinct lines of bedding were observed in any of these quartzyte masses; and their irregular forms, although evidently due to joint structure, indicate that the formation here is not traversed by any regular systems of parallel and intersecting joints.

Mostly the shores of Dam lake are gravelly, with few or no boulders, but nearly all of the surrounding land is till. Back from the quartzyte outcrop the surface is somewhat uneven till, rising from five to ten or twenty feet above the lake within an eighth of a mile, well covered by a moderately large, dense growth of hardwood forest.

Diabase. About three miles southwest from the exposure of the quartzyte, two outcrops of nearly black, rather coarse-grained, very hard and tough diabase occur in the S. W. ¼ sec. 9, T. 46–25, within about a fourth of a mile west from the south end of Long lake and some twenty or twenty-five feet above it. A foot trail

leading from Rabbit lake northeasterly to Dam lake passes over the western and larger outcrop, which has a smooth and somewhat flat extent of about 100 feet from southwest to northeast, with a maximum width of thirty feet, rising only one to two feet above the general surface of the glacial drift. This trap rock shows no traces of flow or shear structure, nor any noteworthy variation in the degree of coarseness of its crystalline texture, throughout its visible area. It belongs doubtless to the central portion of a dike of undetermined but probably not very great width, whose borders and contact with the country rock on each side, presumably quartzyte, are hidden by the drift.

The course of the dike is probably from southwest to northeast, for a second exposure of the same rock is found at a distance of about twenty rods farther northeast, divided from the foregoing by a slight depression of five feet in which there is a grove of several large poplars. The length of this outcrop is about thirty feet, also trending northeastward, and its width fifteen feet. It is partly smooth and even with the adjacent drift surface, some two or three feet above the hollow at the poplar grove; but it also has some fractured spots, on which lie a few boulders or angular masses of the diabase, three to five feet in diameter.

Both outcrops are cut in many directions by numerous joints, nearly vertical or steeply inclined, among which no prevailing system is observable. Slight weathering of these rock surfaces has removed their glacial striation; but the diabase appears to have been more durable to resist decay than the enclosing strata of the country rock, for which reason the dike remains with a greater hight and projects through the drift sheet. A wooded hill of the drift rises within a distance of about a quarter of a mile northeastward to a hight of forty feet or more above the trap outcrops, which lie in a tract having only bushes and scattering small trees. An examination for a considerable distance around failed to discover other rock exposures, but very probably some of small extent will be found if the land should be cleared for cultivation or pasturage.

Mr. Carl E. Taylor, who guided me to these diabase outcrops and to other localities of interest in this southern part of the county, writes under date of October 9, 1894, that he has found another outcrop of the same, or closely similar rock in the east edge of the S. E. ¼ of this sec. 9, T. 46-25, some ten rods from the eastern shore of Long lake, having an exposure of about ten feet vertically, with a brook flowing along its south side and emptying into the lake.

The time of the volcanic or more deeply seated plutonic intrusion of the trap rock here cannot be definitely stated. Quite probably it may have been contemporaneous with the intrusive laccolitic sills of diabase in the Animikie and Keweenawan sedimentary formations on the northwest coast of lake Superior. Dr. A. C. Lawson concludes that those trap sheets and dikes, mostly similar to the diabase in Aitkin county, are of some undetermined age subsequent to the Keweenawan period, which was in the later part of the Taconic era.* They may belong, however, to a very late stage of this era, before its great upper series of detrital and volcanic rocks was completed.

Cretaceous beds. Although no outcrops of Cretaceous strata have been found in Aitkin county, it seems highly probable that shales of this age remain in many places, perhaps upon the greater part of this area, beneath the drift. Fifteen years ago Prof. N. H. Winchell wrote:

> A line drawn from the west end of Hunter's Island, on the Canadian boundary line, southward to Minneapolis, and thence southeastwardly through Rochester to the Iowa state line, would in general, separate that part of the state in which the Cretaceous is not known to exist from that in which it does. It is not here intended to convey the idea that the whole state west of this line is spread over with the Cretaceous, because there are many places where the drift lies directly on the Silurian or earlier rocks; but throughout this part of the state the Cretaceous exists at least in patches, and perhaps once existed continuously.†

This opinion has been well confirmed, and notably by Mr. H. V. Winchell's recent discoveries of Cretaceous shales at several places thirty-five to forty-five miles northeast of Aitkin county, along the elevated Mesabi range.‡ The Cretaceous marine submergence of this region appears thus to have extended eastward, at least to the present site of lake Superior. A large part of the clay of the glacial drift here was doubtless derived by erosion from Cretaceous shales, and their calcareous matter supplied to the drift may principally account for its small amount held in solution by wells and springs in this county, making their water somewhat "hard" and unfit for use in washing with soap.

Glacial and modified drift.

The average thickness of the drift in this county is probably between 100 and 150 feet, this estimate being based on its ascertained thickness in other parts of the state. Wells here obtain ample supplies of water at depths seldom exceeding

*Bulletin No. 8 of this Survey. The aspect of samples brought by Mr. Upham is more like that of an Archæan greenstone than a Keweenawan diabase.—N. H. W.

†Bulletins of the Minnesota Academy of Natural Sciences, vol. i, p. 348.

‡American Geologist, vol. xii, pp. 220-223, Oct., 1893.

twenty or thirty feet, and not one has passed through the drift. Its least thicknesses are on the tract having a few outcrops of the bed-rocks three to six miles south and southwest of Kimberly and in the southeast part of the county, where Archæan rocks rise nearly or quite to the surface.

The boulders and gravel of the drift represent a great variety of rocks which are known in outcrops toward the north, northeast, and east-northeast. Granite boulders are nearly everywhere the most abundant, including usually two-thirds or a larger share of all above one foot in diameter; gneiss, crystalline schists, gabbro, diabase, and other trappean rocks are frequent; but quartzyte, sandstone, and limestone are very rare.

No glacial striæ were found on the few rock outcrops seen; but the prevailing currents of the ice-sheet on this area are known by the directions of transportation of the drift to have been from the north and northeast. The northwestern drift which overspreads the western and southwestern half of Minnesota, containing a considerable proportion of magnesian limestone boulders from formations known in the vicinity of Winnipeg, reached its eastern limit somewhat west of this county.

The largest one of the few limestone boulders observed was found by Benjamin Lamere in plowing on his farm near Hickory postoffice, in sec. 26, T. 46-27. This mass, about three feet in diameter, is a bluish gray, very compact and hard, much jointed magnesian limestone. It contains pyrite in sparsely disseminated, minute grains, and in a few places nodules chiefly consisting of pyrite fill cavities a half-inch or more in diameter, from which the limestone had been dissolved away. The source of this and of the other limestone boulders found very scantly in this county may have been the limestone bands of small extent which are found in the Keewatin series near Ogishke Muncie lake.*

The exceedingly small ingredient of limestone in the drift appears insufficient, as before noted, to produce even the slight degree of hardness of the water of this district, which, therefore, seems attributable to erosion of Cretaceous beds. This conclusion is suggested also by the following analysis of the water of Mille Lacs by Prof. James A. Dodge, for this survey.†

Analysis of the residue from evaporation of the water of Mille Lacs.

	Grains per Gallon.	Percentage.
Silica,	.2499	3.85
Carbonate of lime,	3.1355	28.07
Sulphate of lime,	.1051	.95
Carbonate of magnesia,	3.1589	28.62
Oxide of iron,	.1389	1.26
Carbonate of potash,	.3346	3.03
Carbonate of soda,	1.2241	11.09
Chloride of sodium,	.0817	.74
Organic matter,	2.4458	22.40
Total residue,	10.8745	100.00

Professor Dodge adds: "In regard to the above figures, it is to be noted that the amount of solid residue taken as a whole is not great, compared with that from many waters in this state; that the amounts of lime and magnesia (existing in the water as bicarbonates) are but moderate; that sulphates and chlorides are almost wanting; and that the water is *alkaline*, by virtue of the presence of the carbonate of potash and soda. Upon concentration of this water in a platinum dish a ready and decided test is obtained by litmus and turmeric papers. Further, it was found that nitrates and phosphates are absent. No special examination of the organic matter was made."

Till. Unstratified glacial drift, called till, which was laid down directly by the ice-sheet without modification by water transportation, assorting, and deposition in

* Sixteenth Annual Report, p. 95. Rock sample 1369. Another outcrop of the same is known in Morrison county.
† Tenth Annual Report, p. 205.

beds, occupies probably two-thirds or at least the larger part of this county. In this part of the state the boulders are so plentiful that they are sprinkled numerously on its surface, yet usually not more than the farmer needs to use, for the foundations of buildings and for his cellar and well. They are seldom abundant enough to make walls for the fields, as in New England.

The till is prevailingly dark and somewhat bluish-gray at considerable depths; but it is changed by weathering at the surface and downward commonly five or ten feet to a yellowish-gray, due to the complete oxidation and hydration of its small ingredient of iron, which at still greater depths is mostly in protoxide and anhydrous conditions. In Beaver (T. 46–22) the till has mainly a reddish tint, which doubtless also characterizes it generally throughout the southeastern part of the county, due to the red sandstones and shales of Fond du Lac and the lake Superior basin, and the red volcanic and sedimentary rocks of the same region. Thence eastward to Duluth and Superior, the red color of the till is found to gradually increase in intensity, until the proportion of hematite in the drift about the west end of lake Superior is apparently several times greater than in Beaver township.

Previous pages of this chapter have noted the fertility of the soil upon the till areas, and their usually moderately undulating contour and gentle slopes, which afford excellent drainage and add to their desirability as choice farming lands. They are wooded and have therefore not been so early selected for homesteads or purchase as the prairie lands farther south and west in this state, but they appear to be of fully equal value; and it is to be remarked that for the farmer beginning with little capital their timber supplies his buildings and his fuel, and may often be made a source of revenue while the gradual process of clearing his land goes on.

Terminal moraines. Aitkin county is crossed by two belts of knolly and hilly till, with far more abundant boulders than are found on its smooth tracts before described. These belts were accumulated along the border of the ice-sheet during the stages of halt or slight reädvance interrupting its general retreat at the close of the Glacial period. Throughout the greater part of the duration of the ice-sheet, its currents upon this area probably flowed approximately from north to south; but when the ice became thin under its final surface melting or ablation, the movements of its marginal portion were deflected perpendicularly toward its boundary. Wherever the vicissitudes of the wavering climate caused the waning border to remain nearly stationary during several years the outflow of the ice to its melting steep frontal slope brought and deposited much drift which had been englacial and had become superglacial, being exposed on the surface of the departing ice-sheet. As these marginal accumulations of drift record the position of the terminal line of the ice-sheet when they were formed, the name terminal moraines has been usually applied

to them, but they also may very properly be called retreatal or recessional moraines.

A belt of morainic drift, chiefly till with many boulders, in hills and irregular ridges 50 to 100 feet above the intervening hollows and frequent lakelets, enters this district from Crow Wing county bordering the northwest side of Mille Lacs. Thence it extends with a width of five to ten miles northward to Cedar lake and to the lakes surrounding Deerwood in Crow Wing county, having in this part an unusual expansion and probably marking a northwestwardly re-entrant angle of the ice border. In sec. 30 and the edges of adjoining sections in Hazelton (T. 45-27), comprising the area bounded by Round, Hazelton and Birch lakes, the hills of this moraine are developed in typical profusion and irregularity, attaining hights of 100 feet or more above these lakes. They are similarly prominent west and north of Farm Island, Pine and Hickory lakes, being especially well seen from the west Mille Lacs road one to two miles north of Hickory postoffice. About the southern part of Cedar lake these morainic hills abound and reach elevations 100 to 150 feet above this lake or 1,300 to 1,350 feet above the sea.

Passing from Farm Island and Cedar lakes eastward, the moraine has a width of about five miles, comprising the northern two-thirds of T. 46-27, nearly the same part of the northern township of Nordland (T. 46-26), the southern edge of the next township on the north and considerable portions of T. 46-25 and of Kimberly (T. 47-25). In the southern part of this hilly morainic belt lie Hanging Kettle, Diamond and Mud lakes, the northern part of Elm Island lake, and Cranberry, Rabbit, Long and Dam lakes. At the northeast corner of Kimberly the moraine has a fine development in many bouldery hills upon a width of two or three miles next northwest and north of Portage lake, being there crossed by the Northern Pacific railroad.

If my correlation is correct, the vicinity of Portage lake belongs to a second re-entrant angle, with its apex pointing northeastward, from which the moraine, mostly less conspicuous, turns back and passes by the east side of Dam lake, forms high hills south of Sugar lake, and thence approximately coincides with the eastern watershed of Mille Lacs, until in the southern edge of Aitkin county it curves around to an east and northeast course, passing into Pine county as the hilly belt enclosing the Pine lakes. The series of low drift hills thus traced is provisionally regarded, in the descriptions of its portions in Crow Wing and Pine counties (volume II), as the continuation of the Fergus Falls moraine, which is the eighth in the series of eleven moraines recognized and mapped in their geographic and chronologic succession, crossing the southern and western part of this state.

In northwestern Pine county this moraine is well developed from the Pine lakes northeast to the Kettle river; and farther northeastward I believe that it is repre-

sented by a belt of somewhat hilly drift extending along the east side of the Moose Horn river in southern Carlton county, through T. 46–19, and into Mahtowa (T. 47–18); but thence probably it turns back from a re-entrant angle of the ice front and runs southward through T. 46–18, and eastward past Oak and Net lakes in the north edge of Pine county, to cross the state line nearly on the watershed between the Nemadji and St. Croix basins. A tract of moderately hilly till which I observed one to three miles east of Barnum, and its extension southward by Bear, Hanging Horns, Moose Horn, Long and Moose lakes, belong to this looped morainic belt; and another portion, consisting partially of till with a somewhat rolling surface, but in larger part of low kame-like accumulations of sand and gravel, is crossed by the Great Northern railway in its first three miles southwest of Holyoke.

Such correlation of these morainic tracts seems to be harmonious with the course of the outer moraines in northwestern Wisconsin west and north of the driftless area, as mapped by Chamberlin.* It also accords well with the directions of glacial striæ found very abundant and distinct on the plentiful rock outcrops in the vicinity of Carlton, Thomson, Duluth, and Two Harbors, which run prevailingly west-southwestward, but in very many places also display wide deflections to the southwest and south and to the west and even north-northwest. The divergent and variable glacial currents by which these striæ were made doubtless belonged to the time of recession of the ice-border across that district. We thus learn that the rapidly wasting ice, in its departure from the western end of the lake Superior basin, had a definitely lobate front similar to the looped course assigned to this moraine in Aitkin, Carlton, and Pine counties. Between the times of formation of the eighth and ninth or Fergus Falls and Leaf Hills moraines, as these names are here used, the area of these extraordinary divergent and often intersecting striæ was uncovered by the glacial retreat.

It is further to be remarked that, if the courses of the two moraines of Aitkin county are rightly traced eastward, as noted in the foregoing and following pages, the earliest outlet from the Western Superior glacial lake, held for a time by the barrier of the waning ice-sheet still occupying the central and eastern part of that lake basin, probably flowed across the divide between the head streams of the Bois Brulé and St. Croix rivers, where a remarkable eroded channel is found as described in the chapter on Pine county.† The indentation of the ice-front north of the Wisconsin driftless area at the time of formation of the first or Altamont moraine points decisively to the melting backward of a great re-entrant angle in the ice boundary upon the country between Duluth and Ashland, including the place of the Bois Brulé-St. Croix outlet, at a time previous to the melting of

* U. S. Geol. Survey, Third An. Rep., for 1881–'82, plates xxviii and xxxv.

† Vol. ii, pp. 642, 643.

the ice upon the district reaching west from that outlet to Aitkin county. The correlations given here and in the second volume of the final report imply the probable beginning of the Western Superior ice-dammed lake between the times of formation of the seventh and eighth or Dovre and Fergus Falls moraines. But after the accumulation of the latter and before the time of the next or Leaf Hills moraine, the ice-melting in the western portion of the lake Superior basin and thence west to the Mississippi river was very rapid, so that the greater part of Aitkin county, the whole of Carlton county, and the country from Duluth north to Grand, Wild Rice, and Island lakes, and from Two Harbors north to Highland station, were uncovered from the departing ice-sheet. According to the probable duration of lake Agassiz, estimated to have been only about 1,000 years,* in which the stage between the Fergus Falls and Leaf Hills moraines was a small fraction, this retreat of the ice from Aitkin and Carlton counties and the west end of lake Superior appears to have occupied no more than a century, or perhaps only half a century.

The next halt or reädvance of the ice-border was at the belt of prevailingly knolly and ridged and in part prominently hilly drift, which extends through northern Aitkin county. This belt is probably the representative of the ninth or Leaf Hills moraine which in Otter Tail county is partially united with the Fergus Falls moraine, the two together making the conspicuous Leaf hills (or "mountains," as they are commonly called), 100 to 350 feet in hight above the surrounding country. Entering this county from the west twenty to thirty miles north of Aitkin, low morainic drift hills, mostly twenty-five to fifty or seventy-five feet above the frequent lakelets, swamps, and streams, extend from the vicinity of White Elk or Guide lake northward across the Moose river to Shovel lake and the rapids of the Willow river, which flows over very abundant boulders along a distance of two or three miles next below Shovel lake. Northeastward, drift of similar contour forms the tract, about three miles wide, between the Moose and Little Hill rivers. Close east of the Hill river and south of Hill or Poquodenaw lake, an exceptionally massive portion of this moraine rises in a hill of irregular outlines and slopes, called Poquodenaw mountain, which occupies sec. 25 and the north half of sec. 36, T. 52–26, with its summit about 265 to 275 feet above the Hill lake and river, or 1,525 feet above the sea, being the highest point in Aitkin county. Thence the moraine has a low and inconspicuous development east-northeasterly to the Mississippi river; but near the east bank of the river, about a mile north of this county, it again forms a high hill, known to lumbermen and log-drivers as the "Grub Pile," in the southeast part of sec. 25, T. 53–24, rising about 200 feet above the river.

*Geol. and Nat. Hist. Survey of Canada, An. Rep., new series, vol. iv, for 1888–'89, pp. 50, 51E.

From this hill, as the apex of a re-entrant angle of the ice-sheet, the moraine turns back and extends nearly twenty miles southward to Sandy lake. Along the first six miles of this course it is mainly covered by level or only moderately undulating stratified drift, but in the south edge of T. 52–23 it rises very prominently in Bald bluff, close east of the Mississippi, and in a series of irregular hills continuing thence eastward through the south part of secs. 33 and 34 of this township and the north edge of secs. 4 and 3, T. 51–23. The crests of these hills are 150 to 200 feet or more above the Mississippi, and afford a wide view, the Poquodenaw hill being visible about fifteen miles distant on the west, and the hills of the tenth or Itasca moraine, bordering Pokegama lake, twenty miles away at the northwest. Morainic hills 75 to 150 feet high stretch from Bald bluff southward along the east side of the Mississippi to Sandy lake. Thence this belt, lower and less distinct, consisting partly of kame-like deposits of modified drift and partly of till, curving southeastward, makes the shores and islands of Sandy lake and bounds the northeastern arm of Rice lake, beyond which it passes eastward by Round and Big Island lakes and through T. 49–22, where its low swells, hillocks, and ridges project only twenty to forty feet above the many tamarack swamps.

Eastward from Aitkin county this moraine is narrowly and scantily developed in the northwest corner of Carlton county, but becomes more prominent and broader in the vicinity of Prairie lake, beyond which, as I am informed by Mr. J. E. Spurr, its hills and ridges occupy a width of five to six miles along the south side of the St. Louis river to Stony Brook and Nagonab. Curving northward beyond the St. Louis, it borders both sides of the Cloquet river for several miles, passing northwest of Grand lake.

Gravelly knolls and plateaus. Associated with the till in the moraines, a considerable part often consists of irregularly stratified gravel and sand in knolls and short, irregular ridges, which sometimes become kames. On the general till expanse between the morainic belts, such stratified deposits are also found somewhat frequently in many parts of Minnesota, but are rare in Aitkin county. In both situations they are attributable to deposition by small streams descending from the melting surface of the ice-sheet, being accumulated in the short cañon-like gorges which were melted into the ice-border at their mouths. The slackening of the steep and rapid descent of the streams there emerging upon the land in front of the ice caused them to deposit the coarser part of their load of gravel, sand, and clay, which was left in these hillocks and ridges when their enclosing ice-walls melted away.

Plateaus of gravel and sand, deposited similarly as above, but filling broader indentations of the retreating ice-front, have a considerable development in the

vicinity of Sandy lake. On the northwest shore of this lake, a mile south of the dam, more than half of the pebbles in the gravel of a plateau there rising fifty feet above the lake consist of reddish metamorphic and trappean rocks like formations known to outcrop 50 to 150 miles northeastward. The reddish sandstones which form portions of the Keweenawan series along the north shore of lake Superior are sparingly represented in this gravel.

Low sand and gravel plains. Moderately undulating or nearly level tracts of sand and gravel, spread on the land in front of the retreating ice-sheet by streams which had gathered this modified drift from the melting ice surface, are found in several places, occupying areas a few miles in extent, in the western half of Aitkin county. One of these tracts, enclosed within the most southern and eastern part of the circuitous course of the Mud river, has a diameter of nearly five miles, comprising secs. 27 to 33 and large parts of secs. 20, 21 and 26, in the northern township of Nordland (T. 46–26), and the whole or parts of secs. 4 to 7 in its southern township (T. 45–26). This plain is about sixty feet above Elm Island lake and the Mud river at its northern side, and fifteen to twenty feet above Lone lake, which lies in a deep depression, one and a half miles long and mostly two-thirds of a mile wide, that indents the adjoining flat sand and gravel deposit. When these beds were spread out, the place of the lake and river on the north were occupied by the receding ice-sheet rising above the plain with a steep frontal slope, and the place of Lone lake was filled by a remnant of the ice, left in the capriciously irregular process of its melting to stand first as a peninsula and afterward as an island, around which a flooded river, flowing in the summers from the rapidly dissolving ice and from its heavy rainfall, brought and laid down the sand and gravel plain. The whole tract has a slight inclination, averaging two or three feet per mile, to the south and east; but much of its expanse southward is covered thinly by a mostly unwooded marsh. The avenue of discharge of the water beyond this area was across the swamp, two to three miles wide, which divides it from Mille Lacs.

Another tract of similar modified drift, or perhaps a westward extension of the foregoing, has a length of two miles and width of one and a half miles upon the area partially enclosed by Rice, Hickory and Farm Island lakes, above which its hight is five to ten feet. The surface of both these areas is about five to fifteen feet above Mille Lacs, or 1,255 to 1,265 feet above the sea.

The road from Aitkin to Poquodenaw lake crosses a belt of nearly flat, low sand and gravel, bearing jack pines, through which the Willow river flows in the central and northeast part of T. 51–26. The width of this plain on the road is about two miles, and it extends several miles along the Willow river, widening eastward to the Moose river in Ts. 51 and 52–25, but largely covered there by hay

meadows along the streams and farther northeast, in T. 52–24, by tamarack and cedar swamps.

Such modified drift also borders the lower course of the Swan river, in the north part of T. 52–23, and northward, varying in hight from fifteen to forty feet above the stream.

Thence southward and eastward, through the northeastern quarter of Aitkin county, sand and gravel in low swells and plateaus and in gently undulating areas, interspersed with swamps, occupy much of the country, extending south by Sandy lake to Mc Gregor and the Rice river, and continuing east beyond this district to the Floodwood and St. Louis rivers and thence north in a very broad expanse to the Mesabi iron range.

Lignite in the modified drift. On the site of the Sandy lake dam an excavation about ten feet square, made in the summer of 1893, encountered in the modified drift, at a level a few feet below the river bed, a gravel layer enclosing abundant water-worn and partially rounded lumps of lignite. These masses vary in size from one or two inches to six inches or more in length, and are mostly flattened in parallelism with their bedding planes. It was estimated by Mr. Archibald Johnson, in charge of the construction of the dam, that about two bushels of lignite pebbles were thrown out from this small excavation. They are of quality similar to the lignite coal found in thin layers enclosed in Cretaceous shales near Richmond, Ft. Ridgely, and Redwood Falls in Minnesota, and to the thicker Cretaceous lignite beds which are mined on the Souris or Mouse river and west of Bismarck in North Dakota. Small fragments of lignite are found very rarely in the till of all the western two-thirds of Minnesota, including Aitkin county; and gravel layers in wells near Aitkin occasionally contain smoothly rounded pebbles of very compact, nearly black, carbonaceous shale, somewhat resembling graphite. Occurring so plentifully at Sandy lake, this lignite gravel must have been derived from the erosion of some layer of lignite in Cretaceous shales not far distant northward or northeastward. Indeed, it suggests that perhaps such strata form a nucleus or central mass under the morainic drift of some of the hills on the east side of the Mississippi from Sandy lake north to the Bald bluff.

These observations agree with the discovery of Cretaceous beds on the high Mesabi iron range, noted on a previous page of this chapter, in leading to the belief that deposits of that age lie next beneath the drift in many parts of this region. Concerning this hypothesis, held previous to our learning of the lignite gravel at Sandy lake, Mr. H. V. Winchell has written as follows:

The area at present occupied by Cretaceous is unknown, the mantle of glacial drift covering the underlying rocks to the depth of one hundred feet or more a few miles south of the Mesabi range. There is in St. Louis county an extensive swamp occupying a flat tract of land, running for nearly fifty miles in an east-west

direction between the Duluth & Iron Range railroad and the Mississippi river. The discovery of Cretaceous sediments on the northern edge of this basin suggests the possibility of a considerable thickness of the same sediments in its central portion. From what is known of the geology of the area north of the Mesabi range it is safe to assert that the most promising field for the discovery of workable brown coal deposits in Minnesota is under this same great swamp.*

Only very scanty Cretaceous shale gravel is found in the till and in nearly all the modified drift of this region. The greater part of the Cretaceous beds here, however, may be too soft to yield pebbles, the product of their glacial erosion being principally an indistinguishable part of the fine rock flour or clay in the till. The lignite fragments at Sandy lake are not sufficient, according to the opinion of the writer, to indicate the existence of workable layers of lignite; for they more probably came from thin seams like those known elsewhere in Minnesota, which are mostly about one foot or less in thickness and nowhere exceed three or four feet, being inadequate for profitable mining. Little or no encouragement can be given to prospecting in this thickly drift-covered region with the hope of finding valuable beds of this brown coal.

Lake Aitkin. A glacial lake, which may be named lake Aitkin, existed during a geologically very short time in the broad and shallow depression of the Mississippi valley in western Aitkin county, as is shown by a little beach ridge of gravel and sand which extends along a distance of one mile in the village of Aitkin and westward. The hight of this ridge varies from one to four or five feet above the adjoining surface of till on its southern or landward side, and is slightly greater above its northern or lakeward base; and its width is twenty-five to fifty feet, with an arched, wave-like form and rounded crest, from which there is a steeper descent on the southern than on the northern slope (figure 3). So regular and typical outlines,

FIG. 3. SECTION OF THE AITKIN BEACH.
Horizontal scale, 40 feet to an inch; vertical scale, 20 feet to an inch.

however, are not found through the whole of the distance noted. A section made for a north to south street a few rods west of William Hay's house shows the ridge to be composed of anticlinally interbedded sand and gravel, in which the largest pebbles are three to six inches in diameter. In form and material it is precisely like the beach ridges marking successive stages in the gradual lowering of the glacial lake Agassiz in the basin of the Red River of the North, some of which are no larger along the greater part of their course, though traceable continuously many miles on the prairies of the Lake Agassiz area.

The most eastern observed part of this very small ridge is close west of the Mud

* Am. Geologist, vol. xii, p. 223, Oct., 1893.

river between the railroad bridge and the Congregational church. Thence it runs northwest and west, passing just north of the intersection of Ash street and Third and Fourth streets, to the Methodist church and the school house. In the west edge of the village the houses of S. W. Stevenson and William Hay are built on the beach. It continues west-southwesterly to the Cedar Lake road and the railroad, which it crosses nearly a mile west of Aitkin depot. Excavations of the beach sand for masons' use have been made there by the roadside. Its further course westward upon bushy and wooded land has not been traced, nor its similar extent east of Aitkin; but four miles west of Aitkin a small portion of this shore line, marked by a beach ridge, was seen on a farm in the S. E. $\frac{1}{4}$ of sec. 30, Aitkin, extending thirty rods or more from east to west a short distance north of the Northern Pacific railroad and about a quarter of a mile west of Cedar creek. In both these portions the beach crest is 1,210 to 1,212 feet above the sea, and the lake level indicated is 1,205 to 1,208 feet.

Drawing on the maps of Aitkin and Crow Wing counties the approximate extent of this lake, I find that it probably attained a length of eighteen or twenty miles, terminating northeastward near the mouth of the Willow river, and that it was mainly from three to five miles wide. If no allowance is made for the subsequent deposition of alluvium in the valley, the maximum depth of lake Aitkin did not exceed fifteen feet. In the vicinity of Rabbit lake in eastern Crow Wing county north of Deerwood, morainic drift about 1,275 feet above the sea closely borders the Mississippi. There the margin of the ice-sheet receding northwestward was probably, during a few years, a partial barrier of this lake, whose outflow was in some channel about seventy-five feet below the top of the contiguous moraine and twenty feet above the present river. Till generally forms the surface south of the Aitkin beach; but on its lakeward side the land is lacustrine and alluvial fine silt or clay, more or less sandy.

Formerly higher levels of Mille Lacs. The north side of Mille Lacs exhibits shore lines in many places at hights five to ten or fifteen feet above the present highest stages of the lake, which are four or five feet above its lowest known level due to droughts. The old higher shores are partly marked by small beach ridges, of which, in two localities where they were carefully observed and mapped because they are the sites of aboriginal mounds, descriptive notes are given on the final pages of this chapter.

A more massive wave-built beach ridge, mostly well wooded, divides Mille Lacs from a marsh or swamp and other low land on the north along a distance of five or six miles, from near Get-Up point eastward past the mouths of Reddick and Marmon creeks to the west part of T. 45-25. The western half of this ridge,

for a length of about three miles, has a hight of ten to twelve feet above the lake and a width of six to ten rods, with gentle slopes, and consists of beach sand and fine gravel containing no boulders. The road from Aitkin to Malmo and Opstead runs along its top. Farther east this ridge, still consisting mostly or entirely of sand and gravel without boulders, and having not much greater width than westward, rises steeply fifteen to twenty feet above the adjoining gently sloping present lake beach on which the road lies. Its crest in the highest places is about twenty-five feet above the lake. The formation of the whole ridge seems referable to wave action during storms, eroding the till shores both east and west of the ridge, and washing the sand and gravel thence derived along the shore, building it outward from each end, but most from the east, to form this beach embankment.

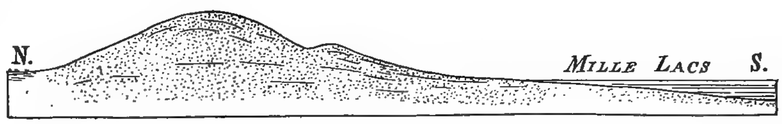


FIG. 4. SECTION OF THE MILLE LACS BEACH.
Horizontal scale, 100 feet to an inch; vertical scale, 50 feet to an inch.

The level of the lake indicated for the higher eastern part of the embankment appears to be nearly fifteen feet above its present mean level. Storm waves then, in the deeper lake, impeded much less than now by friction on the bottom near the shore, doubtless rolled in from this broad expanse of water with sufficient power to build a beach ten or twelve feet high. Along this eastern part of the ridge a secondary lake level, intermediate between the earliest and the present, is recorded in some places by a minor beach crest, about ten feet above the lake, upon the southern face of the great embankment, as shown in figure 4. The average stage of water thus known, some five to seven feet above the present, probably endured longer than the first and higher stage, for it built the western low but broad part of this ridge, though the lake was shallower than before and its waves less efficient, and it is very clearly marked in the vicinity of the two groups of artificial mounds.

It will be desirable, for comparison with these observations, to search along the southern shores of Mille Lacs for similar traces of formerly higher lake levels. If they exist there at corresponding hights, the explanation of them all will be that erosion by the outflowing Rum river has lowered its channel successively from the higher to the lower and present stages of the lake. Very probably no such ancient shore lines will be found on the south side; and if this be the case, the apparent high stages of the lake at the north must be attributed to a differential uplifting of this region, raising the northern shore faster than the southern, in the same way as the basin of the glacial lake Agassiz was uplifted during the

departure of the ice-sheet. The highest and earliest beaches of lake Agassiz ascend about one foot per mile along a distance of 350 miles from south to north, between lake Traverse at its outlet and Riding mountain in Manitoba. A similar and contemporaneous differential movement of the earth's crust beneath Mille Lacs and Aitkin county would account for the early northern shores successively about fifteen and seven feet above that of to-day.

Ridges pushed up by ice on lake shores. Besides the ridges thus far described, the shore of Mille Lacs in other places, where it is bordered by slowly rising slopes of till, has a conspicuous ridge of sand, gravel, and boulders, immediately adjoining the water's edge or separated from the lake only by a low and very narrow strip of sand and gravel. This predominant type of the ridge accumulation now taking place is well exhibited along an extent of a half mile at and near Nichols postoffice. An embankment there pushed up by winter ice during the many centuries since the lake has held its present level, with much addition of wave-washed sand and gravel, occupies a width of four or five rods, rising in rounded slopes and crest eight to ten feet above the stage of high water. The frequent, or in some portions plentiful, boulders of this ridge prove that the deeply frozen ice of the lake pushed boulders from its bed and at last thrust them high on the shore when the breaking up of the ice in spring permitted its blocks to be crushed and heaped together by violent storms.

Similar but smaller sandy and gravelly ridges enclosing boulders, often very steep on their lakeward side, and narrow, as two or three rods wide, with hights of three to six or eight feet, are found on the shores of numerous other lakes in Aitkin county. One of these ridges borders Dam lake on the side of its outlet; another, with a road running a half-mile or more along its top, is on the south shore of Hazelton or Echo lake; and others are on the east and west sides of Round lake, and on the west side of Farm Island lake.

Alluvium. Since the departure of the ice-sheet, the streams have in many places eroded their channels ten to twenty or thirty feet below the original surface of the drift, either through long distances or more commonly only cutting down some obstructing narrow ridge or swell of the undulating and rolling drift sheet. Taking their courses along the lowest avenues of drainage, the creeks and rivers were at first temporarily dammed here and there to form shallow lakes, which in many instances they very soon drained by their erosion of the drift barriers. On some of the streams, however, as most notably the Mud river, the ratio between the size of the rivers and the erosion which they must perform to drain their lakes will allow them to endure yet a long time. Into these lakes much alluvium, supplied from the erosion of the tributary valleys, is being carried by the inflowing streams, and less is spread along the interlacustrine parts of their courses.

The Willow river and the much larger Mississippi, nowhere in this county flowing through lakes, have formed extensive tracts of very fertile alluvial land, bearing a luxuriant forest. The tract of very fine clayey silt through which the Mississippi pursues its meandering way varies mostly from a half-mile to one mile in width. It is rarely interrupted, as at a few places between Sandy lake and Aitkin, by transverse higher areas where till adjoins the stream and makes shoals and rapids by the obstruction of its boulders in the river bed.

MATERIAL RESOURCES.

The chief resources of Aitkin county are its timber, its capabilities for agriculture, and its water-power. Thickly drift-covered, it possesses no rock outcrops adapted for quarrying, and warrants no expectation for the discovery of geologic deposits of economic value, excepting that probably stratified clay beds suitable for brick-making will be found in some places.

The original forest wealth of this region is being rapidly exhausted. During the winter of 1892-'93 the estimated cut of pine timber on the Mississippi and its tributaries above Minneapolis, according to the records of the surveyor general, was 677,836,540 feet, of which the following portions were wholly or partly in Aitkin county.*

Pine timber cut during the winter of 1892-'93.

	Feet.
Little Willow river,	5,000,000
Willow river,	55,000,000
Aitkin and vicinity,	3,370,730
Rice river,	11,353,260
Sandy lake and river,	7,549,570
Tamarack river,	19,692,750
Prairie river (tributary to Sandy lake)	4,621,750

With a continuation of the recent rates of cutting, no more than ten or twenty years will elapse until all or very nearly all of the available pine in this county will have been used. But a very large supply of other valuable timber will remain, as poplar for the manufacture of paper, and maple, oak, birch, and ash, for furniture, carriage-making and a great variety of uses, including building, for which, however, pine is preferred. In clearing the land of its woods to provide fields for cultivation and pasturage, the farmer will often be able to make the timber do more than pay for the cost of its cutting and the removal of its stumps.

A foregoing part of this chapter has noticed the general excellence of the soil of the boulder-clay or till which covers the greater part of this county. The alluvial lands bordering the Mississippi are still more fertile and are wholly free from boulders and gravel; but they mostly lie within the reach of the highest river floods, which come, on an average, perhaps once in ten years, being due usually to coincidence of heavy rainfalls, with rapid melting of deep snows at the end of the winter. Large fields of the river alluvium within a few miles northeast of Aitkin, on the road to Willow river and Sandy lake, bear magnificent grass, oats, potatoes and corn. A considerable number of farms have also been cleared and are profitably cultivated on the higher till lands in the vicinity of Aitkin and Cedar lake, and thence southward to Mille Lacs. The success of these farmers in producing the staple crops mentioned, and in stock-raising, dairying and fruit-raising, justify the belief that this county is to become a thickly settled and prosperous agricultural district.

As a resort for sportsmen, both in summer and winter, Aitkin county has many attractions, which will be slowly decreased by its agricultural development, but in some measure will endure through many decades of years. The plentiful lakes contain abundant bass, pickerel, perch, and other fish. Partridges, rabbits, the mink, muskrat, and fox, the black bear, red deer, and moose, are common or frequent. Occasionally in the winter, timber wolves, hunting in packs, are dangerous to lone travellers; but their numbers are gradually diminishing. Another vanishing denizen of this region is the caribou or American reindeer, whose southern limit is found in cool bogs about the sources of the Little Willow river.

Excepting perhaps the Mississippi, all the large streams of this county have valuable sites for the utilization of their water-power. No mills employing water-power, however, have been built, but large steam saw mills are operated at Aitkin and at the Swan River Logging Company's landing close to the mouth of

* *The Mississippi Valley Lumberman* (Minneapolis), June 30, 1893.

Swan river, and smaller portable mills have worked temporarily at numerous other localities. Dams are built on several streams to provide reservoirs for giving a sufficient flow of water in the later part of the log-driving season which usually reaches into the summer. When required by the needs of the increasing population, water-power mills will doubtless occupy some of these sites for grinding grain, sawing lumber, and various manufactures.

Dams used for lumbering.

The following are notes of the locations and amount of head, or fall of water, of the dams used to facilitate log-driving in Aitkin county, for which on the west side of the Mississippi I am indebted to Martin M. Watson of Aitkin, and on its east side chiefly to F. B. Cluff and Joseph W. Wakefield of Aitkin.

Little Willow river, four dams: the lower dam in the S. W. ¼ sec. 30, T. 48-26, six feet; the middle dam, near the centre of sec. 8, in the same township, seven feet; the Esquagemaw dam, on the West fork, close below the mouth of Little Willow or Esquagemaw lake, which it flows, five feet; and the Waukenabo dam on the East fork or Waukenabo brook, or about a half mile below the lake of this name, three feet.

Willow river: the Shovel lake dam, in the north edge of sec. 3, T. 51–27, situated at the head of the boulder-strown rapids, about two miles long, which take their name from this lake, has a head of six feet and raises Shovel lake five feet above its former low water stage. This is the lowest of seven dams on the Willow river and its North and South forks, the others being in Cass county.

Moose river, six dams: the Moose lake dam, near the centre of sec. 27, T. 51–26, five feet, flowing Moose lake; the McAllister dam, in the west edge of sec. 29 in the same township, seven feet; the McKinney dam, in the S. E. ¼ sec. 23, T. 51–27, eight feet, flowing McKinney lake; the Third Guide dam, in the N. E. ¼ sec. 28, flowing the little Third Guide lakes; and the two following, which are in Cass county, namely, the Cedar dam, in the northeast corner of sec. 35, T. 140–25, five feet, and the Reservoir or Poplar dam in the S. W. ¼ sec. 2, T. 139–25, six feet.

Hill river and its tributaries, four dams: the Poquodenaw dam at the mouth of Hill or Poquodenaw lake, seven feet; the Morrison brook dam, about a mile from the mouth of this brook, six feet; the Lower dam on the West branch or Little Hill river, in or near the southwest corner of sec. 33, T. 52–26, eleven feet; and the Upper dam of this stream, in the south edge of the southwest part of sec. 36, T. 53-27 (Itasca county), about five feet.

Mud river, two dams: the Lower or Simpson dam, three miles south of Aitkin, five or six feet, flowing the Hanging Kettle, Diamond and Mud lakes; and the Spirit lake dam, in the N. E. ¼ sec. 35, T. 46–27, five feet, flowing Spirit, Hickory, Pine and Farm Island lakes.

Sandy river, two dams: one about a mile north of McGregor, four feet; and the United States government dam, now being built to raise this lake ten feet, as described on page 29.

Tamarack river, four dams, three being in Carlton county: the lowest in the east edge of Aitkin county, about five feet, now out of repair; the second, about a quarter of a mile east of Wright and close south of the railroad, four feet, flowing Tamarack lake; the third, at Cromwell, two feet, flowing Island lake; and the fourth, probably about four feet, flowing the lake in secs. 17 and 18, T. 48–20.

Prairie river, three dams, only the first and lowest being in Aitkin county: one raising the stream along the course of a short rapid in the south part of T. 50–22, about four feet; the second, two miles below Prairie lake, four feet, at the foot of which the channel of the river is said to have exposures of the bed rock; and the third, about a quarter of a mile from the mouth of Prairie lake, which it flows, five feet. Hasty brook, tributary to Prairie lake on its south side, has two dams, the lower of five feet, and the upper of seven feet, the latter forming a reservoir on a tract that previously was a large meadow or swamp.

West Savanna river, three dams: the Sanders dam, in the N. W. ¼ sec. 25, T. 50–23, about two miles above the junction of this stream with the Prairie river, four or five feet; the Wakefield dam, in the southeast corner of sec. 13, near the east line of this township, five feet; and the upper dam, in the southwest part of sec. 6, T. 50–22, six feet, flowing the Savanne lake. Above these, a low "cut-away" dam raises the Rice lakes in secs. 36 and 35, T. 51–23, about two feet.

Aboriginal earthworks.

Two very interesting groups of aboriginal mounds are situated close to the northern shore of Mille Lacs, one being at Nichols postoffice, a mile east from the west line of Aitkin county, and the other at E. A. Bushey's store, twelve miles distant from Nichols in a straight line a little to the north of east. Looking in a general view upon the outlines of Mille Lacs, we may consider its area as four-sided, its northwestern and northeastern corners respectively being near these ancient village sites.

The accompanying sketch map (figure 5) shows the arrangement, relative size and hight of twenty mounds lying between the house of Mr. A. R. Nichols, postmaster, and the present Mille Lacs shore. The house stands upon and two or three feet above a former shore of the lake, which is marked by a slight terrace of sand and gravel, seven or eight feet above the present highest stage of water. Between this old shore and the prominent lake ridge now being accumulated of sand and gravel with occasional boulders, which has been described on page 49, there are two very small beaches, marked by sand ridges, fifteen to twenty-five or thirty feet wide and rising only about two feet above the flat, somewhat clayey land on which they lie. The crest of the northern one of these is about six feet, and that of the southern one four to five feet above high water in the lake. Five mounds, varying from two to five feet in hight, are found in a nearly straight series, extending about a dozen rods, on the upper one of these little beach ridges. All of these mounds are round,

excepting the most eastern and highest, which is prolonged in a lower portion toward the west. Twelve mounds are situated on the lower sand beach, forming a very straight series along a distance of nearly thirty rods. Beyond each series of mounds the beaches continue westward, having in some portions an irregularly uneven contour with elevations and depressions of one or two feet, due to the dune-producing action of winds. These surface inequalities of natural origin are smaller and less noticeable than the artificial mounds, among which little or no wind channeling is observed.

The mounds of the second series, like those of the first, are mostly built to a hight of about two feet above the beach crest, with a diameter of fifteen or twenty feet; but one, the fourth from the west end, is nearly four feet high. Several of the mounds in the eastern half of this series are elongated, having about twice as great length as width. In the depression on the south, two small round mounds lie near the oblong mounds of the beach ridge. About ten rods southeast from these and south from the east end of the longer series, a round mound rises to a hight of two feet upon the crest of the large modern beach ridge.

In Mr. Nichols' garden, which comprises most of the mounds of this group, numerous fragments of Indian pottery have been found; and they occur more plentifully in one of his cultivated fields, a quarter of a mile distant to the northeast and near the lake shore.

Another group of several artificial mounds near this northwestern angle of Mille Lacs is situated about two miles southwest of Nichols postoffice and a third of a mile back from the lake, being near the middle of the west half of sec. 12, Garrison (T. 44–28). The largest of these mounds, about ten feet high, was partially

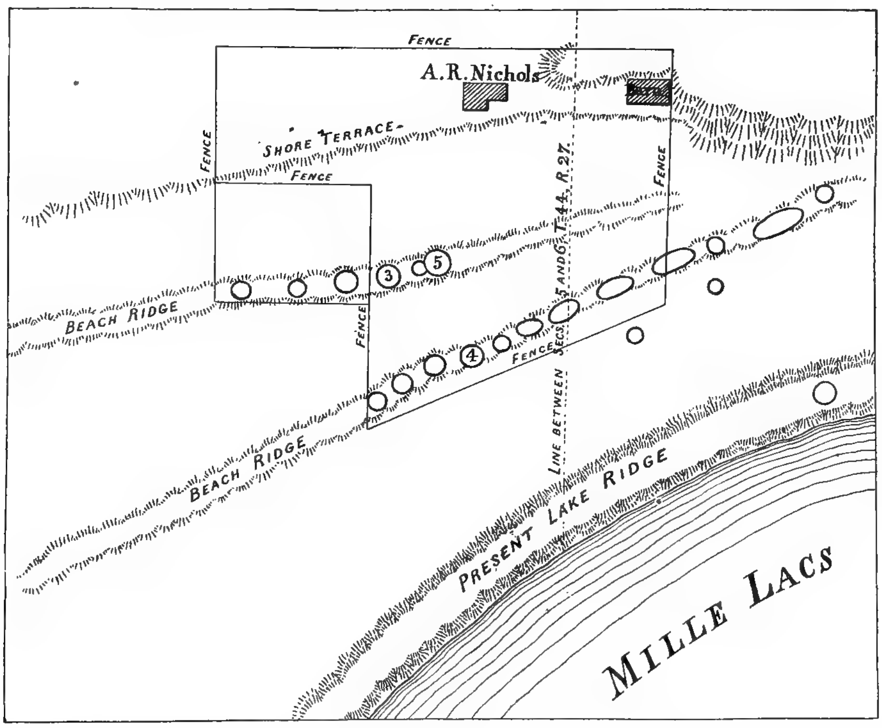


FIG. 5. ABORIGINAL MOUNDS AND BEACH RIDGES IN SECS. 5 AND 6, T. 44–27, AT NICHOLS POSTOFFICE.
Scale, about 160 feet to an inch.
The mounds are about two feet high, excepting three, whose hights in feet are designated by figures.

excavated by the late Mr. O. E. Garrison and others, and was found to contain human bones. One other mound of that group, nearly as large, has not been opened. No other aboriginal earthworks are known in the vicinity of these groups.

Passing along the northeastern shore of Mille Lacs, on the road from Aitkin to Malmo and Opstead postoffices, the traveller sees at the store of Mr. E. A. Bushey, which is in the northwest corner of sec. 32, T. 45–25, and in his cleared field of a few acres, extending some thirty rods to the east and southeast, a group of eighteen aboriginal mounds, of which a sketch map is given in figure 6. More than half of these mounds are from two to (mostly) three feet high; a half dozen have hights of four or five feet, and only one is larger, having a hight of nine or ten feet above its base, with its crest twenty feet above the lake. All of these are round and dome-shaped, with diameters varying, in proportion to their hights, from fifteen or twenty feet to fifty feet; except that the highest mound has another about three feet in hight adjoining and united with its northeast side. The tract on which they lie is stratified gravel and sand, rising to a hight of ten to twelve feet above the lake. It has a rich black soil, and was cultivated as a cornfield at the date of my visit in June, 1893.

An arrangement in three series, nearly parallel with each other and with the lake shore, each comprising four or five mounds, is observable. Between the lake and the nearest one of these series, three small beach ridges of sand, similar to those at Nichols postoffice, are well defined across the entire clearing. On the beach farthest (eight to ten rods) from the lake, three mounds are situated, and the highest and most northern of these is the site of Mr. Bushey's stable. This beach ridge and its parallel companion, which lies about two rods nearer the lake, each rise only two feet above the intervening hollow and above the land on the side away from the lake. Between the second of these ridges and the one nearest the shore, on which latter Mr. Bushey's store and a mound close north of it are situated, there is a continuous long hollow five feet below these beach crests, which, like that of the first beach, are each ten feet, very closely, above the lake level. Intervening between the last beach and the present shore is a gently declining belt of sand and fine gravel on which the road lies. None of these mounds have been excavated.

Nearly thirty miles northeast from these Mille Lacs village sites, two similar groups of mounds lie on the southeast side of the Sandy river near its entrance into the most southern arm of Sandy lake (see the figure on page 29). One of these groups, comprising several mounds three to six feet high, is at the river's mouth in the

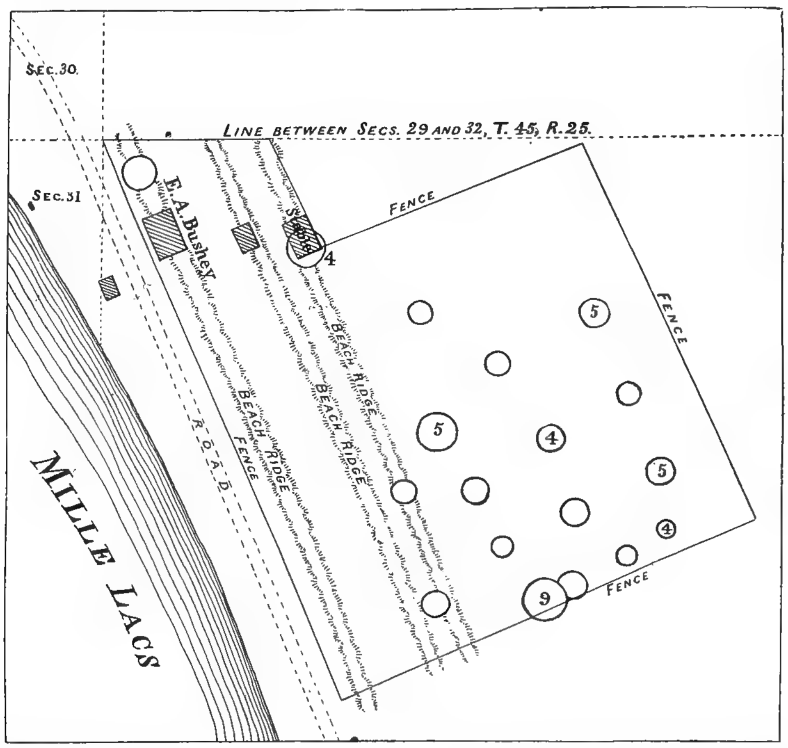


FIG. 6. ABORIGINAL MOUNDS AND BEACH RIDGES IN THE N. W. ¼ SEC. 32, T. 45-25, AT E. A. BUSHEY'S STORE.
Scale, about 160 feet to an inch.
The mounds are two or (mostly) three feet high, excepting several whose hights in feet are designated by figures.

southwest corner of sec. 17, T. 49-23. The other, marking the place of a larger village, includes about twenty mounds, which vary from three to ten feet in hight. It is distant one and a half miles southwest from the foregoing, and extends about a quarter of a mile along the river's east bank next below its exit from the rice lake which is crossed by the west line of sec. 30 of this township.

The people who built the mounds were doubtless of the same great race with the present Indian tribes. Their numbers appear to have been similarly few, and they probably were but little more advanced in agriculture. Like the modern tribes of this district, they evidently obtained a considerable part of their sustenance by fishing in the lakes and rivers on whose shores they lived.

In the neighborhood of the outlet of Sandy lake, which flows deviously about three miles to accomplish its one mile of distance between the lake and the Mississippi river, a few Indians still remain, holding this locality of the old trading posts as their latest place of abode and ownership in Aitkin county. There is little trace of any earthworks to show that this site was occupied by the mound-building people, though its natural beauty and advantages for fishing and hunting must have been as attractive then as now. Numerous arrow and lance points of stone, and several of copper, besides curved bands of copper which probably were worn as ornaments, have been found here on or near the surface by Mr. William L. Wakefield, the merchant and postmaster,

who also showed me a copper spear-head, nine inches long, which was found in the mud beneath the river bed during the excavation for the dam (page 29). This implement (figure 7) somewhat resembles a bayonet blade,

FIG. 7. COPPER SPEAR-HEAD FOUND AT SANDY LAKE.
About one-third of the full size.

and like that, its base is convolute, as if for fitting it upon a wooden shaft. All these copper implements and ornaments appear to have been worked out by the Indians from native copper of the lake Superior region, which may have been either mined there by them or found here in the glacial or modified drift.


BELTRAMI COUNTY
CASS LAKE
LAKE WINNIBIGOSHISH
ITASCA
MISSISSIPPI RIVER
GREAT NORTHERN RAILWAY
PIKE BAY
CHIPPEWA INDIAN RESERVATION
NORTHWEST PART OF CASS COUNTY
LEECH LAKE
LEECH LAKE AGENCY
LEECH LAKE INDIAN RESERVATION
HUBBARD COUNTY
AITKIN COUNTY
WADENA COUNTY
WHITEFISH LAKES
PELICAN LAKE
GULL LAKE
LONG LAKE
SYLVAN LAKE
CROW WING RIVER
BRAINERD
MOTLEY
TODD COUNTY
MORRISON COUNTY
GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA
CASS COUNTY PLATE
BY WARREN UPHAM.
Explanation
Contour Lines

CHAPTER III.

THE GEOLOGY OF CASS COUNTY AND OF THE PART OF CROW WING COUNTY NORTHWEST OF THE MISSISSIPPI RIVER.

BY WARREN UPHAM.

Situation and area. The district here described (plate 58) comprises the greater part of Cass county and that part of Crow Wing county which was taken from Cass and annexed to Crow Wing in 1887. The northwestern fraction of Cass county, including twelve townships, or about 432 square miles, in ranges 32 to 35, north of Hubbard county, is described and mapped with that county, in the next chapter. The most southern limit of this district is a few miles north of the geographic centre of Minnesota. Its extent from south to north is eighty-two miles, and from east to west forty-eight miles.

The Northern Pacific railroad passes through its southern edge, past the stations of Baxter, Gull River, Sylvan Lake, Pillager, and Wheelock. None of these stations has now any considerable village, since that of Gull River, formerly the location of the large saw-mills of the Gull River Lumber Company, has been chiefly removed, with the mills, to Brainerd. The only place in the entire district which can at present be designated as a village is the Leech Lake Indian Agency, which has, besides a school, church, and other government buildings, some forty or fifty houses of Chippewa Indians.

Brainerd, situated on the east side of the Mississippi river, just outside the boundary of this district, is distant 138 miles by railroad north-northwest from St. Paul, and about 118 miles by railroad, or very closely 100 miles in a direct line, west-southwesterly from Duluth. The part of Crow Wing county on that side of the Mississippi has been mapped and described in chapter xxii of volume ii; but a few notes of Brainerd and its vicinity, supplementary to that chapter, are presented in the following pages.

The present area of Cass county is about 2,832 square miles. Its portion shown on plate 58 is 2,400 square miles very nearly; with which are also mapped about 610 square miles of Crow Wing county, making the area included by this plate approxi-

mately 3,010 square miles. Of this area nearly a fifth part, or some 600 square miles, is occupied by lakes and rivers.

SURFACE FEATURES.

Natural drainage. The Mississippi river forms a large part of the northern boundary of Cass county, flowing through Cass lake and lake Winnibigoshish. After its farther course to the east, south and southwest, through the south part of Itasca county and through Aitkin county, the Mississippi again bounds this district on the southeast side, there flowing through Crow Wing county; and its large tributary, the Crow Wing river, is the southern boundary of Cass county. These two main streams receive the drainage of this whole district, by many smaller rivers, creeks, and brooks.

Leech Lake river, bringing the outflow of the lake of this name, is the principal tributary of the Mississippi from northern Cass county. Into this lake, the largest in the group of many lakes feeding the upper Mississippi, several small streams flow, namely, the Steamboat and Kabecona rivers, from the west; the Shingobi creek, and three or four smaller brooks, from the south; and the Boy river, the largest affluent of Leech lake, from the east, coming, however, through a region of many lakes on the south and southeast.

The remainder of Cass county and the northwestern part of Crow Wing county are drained into the Mississippi chiefly by the Pine and Crow Wing rivers. Pine river, about forty miles long, flows through Pine Mountain lake, lake Hattie, Norway lake, Whitefish, Rush, Cross, and Pine lakes. Its principal tributaries are the South branch, coming in from the west about two miles south of Norway lake; Daggett brook, receiving the waters of numerous lakes, and flowing into Cross lake; and the Little Pine river, which joins the main stream about three miles from its mouth.

Crow Wing river receives, as small tributaries from the southwest part of Cass county, Farnham brook, Swan creek, Mosquito brook, and Pillager creek;* and the Gull river, about thirty-five miles long, flows through lake Sibley, Mayo lake, and the Upper and Lower Gull lakes, joining the Crow Wing river three miles above its confluence with the Mississippi, which is at the most southern point of this district.

Lakes. Excepting about a dozen townships in the southwestern part of Cass county, lying in ranges 30 to 32, this whole district is very abundantly sprinkled with lakes and lakelets, which vary from a length or diameter of a quarter of a mile, or less, upward to Leech lake, which is the third in size among the lakes lying wholly in Minnesota.

* The terms *brook* and *creek* have the same meaning and nearly equal frequence of usage in this wooded region; but in the prairie part of the state only the second term is in common use.

The maximum length of Leech lake* is twenty-four miles, and its greatest width twelve miles, with an area of about 165 square miles, bounded by a very irregular outline of many arms and bays, and containing several islands. According to soundings by Dr. James R. Walker, formerly the agent of the Leech Lake reservation, this lake in the central portions of its main body attains depths of fifty to sixty feet; in the broad bay extending to the outlet its depth is twenty-five to forty feet; in the bay north of Otter Tail point, twenty to thirty feet; in Duck bay, about twenty feet; in the West bay, somewhat southeast of its centre, 100 feet; and in the southeastern part of the Agency bay, seventy-two feet. The dam built by the United States government to make Leech lake a part of the reservoir system of the upper Mississippi raises its surface usually two or three feet above its former hight, and its maximum capacity is about six feet above the former low water stage.

Lake Winnibigoshish,† the largest of the lakes through which the Mississippi flows on and near the northern border of Cass county, is about eleven miles long by six to eight miles wide. It has no islands, but is shallow, with a maximum depth probably not exceeding twenty or twenty-five feet.

Cass lake,‡ about six miles long and three to five miles wide, with several islands, is also mostly shallow, its maximum soundings being reported to be twenty-two feet. A short river-like thoroughfare leads southward from this lake into Pike bay,§ three miles in diameter, which has probably a somewhat greater depth.

Two tracts characterized by exceptionally abundant lakes are found in the central and southern parts of this district. The first of these tracts, mainly tributary by the Boy river to Leech lake, has an extent of about thirty miles from west to east and northeast. It is divided from Leech lake by the greater part of the hilly drift belt of the Itasca moraine, five to ten miles wide, within whose southern borders a large number of the more southern of these lakes are enclosed. Ten Mile lake, the head of the Boy river, is the largest in this tract, its length being nearly six miles, with a mean width of one to two miles. Next southeastward is the Fourteen Mile lake, about three miles long, and, like the preceding, of very irregular form, through which flows the Boy river, or Fourteen Mile creek, as the outlet of this lake is named from its being crossed by the road at that distance from the Leech Lake Agency. Between one and four miles farther eastward, this stream flows through the Little Whitefish and Whitefish lakes, as Mr. James B. Curo, living near them, informs me that they are called by the Indians. Thence the Boy river flows through two lakes, respectively two miles and one mile long, in the southwestern and central parts of T. 140-29. Woman lake (a translation of its aboriginal name), lying next in the course of the river, has a length of about five miles and a maximum width of two miles, with very irregular form. Beyond this the stream continues through Girl lake, Rice, Upper Boy and Boy lakes, the last, which is the largest, being about five miles long and a half mile to one and a half miles wide.

Rice lake, in this series, receives the largest tributary of the Boy river, bringing the outflow, in descending order, of Waupatoos, Wabado, and Little Boy lakes, which lie in the southern and central portions of T. 140-28. The first and second of these lakes, connected by a broad thoroughfare, were formerly of the same hight with Little Boy lake and joined with it by a second thoroughfare; but now the two are raised about three feet above the third by a dam near the bridge of the Mississippi & Northern railroad. Girl and Woman lakes are also

*A translation of its Ojibway name, in allusion to its plentiful leeches.

†Meaning *dirty water* (Fifteenth Annual Report, p. 459), like the cognate name of lake Winnipeg in Manitoba. On account of the shallowness of lake Winnibigoshish, the large waves of storms stir up the mud and sand of the lake bed, roiling the water upward to the surface upon nearly or quite all its area. Pronounced by the Indians, and perhaps more properly to be spelled, like lake Winnebágo in Wisconsin, which is accented on the next to the last syllable, with the addition of *shish*, expressive of contempt, the name being thus Winnebágoshish. Lieut. Pike, in 1806, found this lake to be called "Winepie" and "Winipeque." Beltrami, in 1823, mapped it as "Winnipec;" and Schoolcraft, in 1820 and 1832, gave the same spelling, also "Winnipek." Since their time the name of this lake seems to have grown to its present form, which is nearly represented by "Winibigoshish" of Nicollet's report and map, in 1836.

‡Named for Gov. Lewis Cass, commander of the U. S. expedition which ascended the Mississippi to this lake, in 1820.

§Named for Lieut. Z. M. Pike, who led an expedition to Leech and Cass lakes during the winter of 1805-'06. For notes of the early explorations in this district by Pike, Cass, Beltrami, Schoolcraft, and Nicollet see vol. i, pp. 25-78.

made reservoirs by another dam, with nine feet head, on the Boy river close below its crossing by this railroad, which is used for the transportation of logs from this river south to Cross lake on the Pine river.

The more southern portion of this tract of lakes is tributary to the Pine river by its North branch, which in successive parts of its course is known as Pine Lake brook, Twenty-four Mile creek, and Norway brook. Its highest sources are the two little Jack Pine lakes in the southwest part of T. 140–31. Thence it runs through Pine Mountain lake, three miles long and averaging about a mile wide, Rice lake, two nameless lakes next eastward in the southern edge of T. 139–30, lake Hattie, and Norway lake. Between the last two of these lakes, it receives Ada brook, bringing the outflow of Ada and Hand lakes, respectively two miles and one and a half miles long, and of several others of smaller size.

Nearly connected at the north with the eastern portion of the foregoing tract of many lakes, the second tract reaches from north to south and south-southwest across this district. Its northern part includes Mud lake on the Leech Lake river, and numerous lakes, ranging upward to two miles in length, outflowing by the Bear and Vermilion rivers; and farther east, in the southwestern corner of Itasca county, it reaches to Sugar and Pokegama lakes and others close to the Mississippi river above Pokegama falls. Continuing to the south, this tract comprises, on the Willow river, Big Rice lake, three miles long and nearly two miles wide, shallow and bearing along its shores much wild rice, one of the chief food resources of the Indians. Thunder lake, lying southwest of the last, about three miles long, naturally tributary to the Boy river, has been turned by a dam four feet high across its former outlet, and by a very short ditch connecting it with Little Thunder lake, so that the outflow of both these lakes now runs into the Big Rice lake and Willow river, increasing the supply of water in that stream during the season of log-driving. Lake Laura, on the former outlet, because of this loss of its inflowing stream, is now drying up.

Farther to the south, the central portion of this tract has a large number of lakes whose surplus waters are carried to the Mississippi by the Pine river and its tributaries. In this stretch of about twenty-five miles are lakes George and Washburn, Crooked lake, Mitchell, Eagle, Fox, Daggett, and Pine lakes, outflowing by Daggett brook; Cross, Rush, Whitefish, Trout, and Lower Hay lakes, all of which, as also Daggett and Pine lakes, are made reservoirs by the Pine river dam, at the mouth of Cross lake, built by the United States government, having a maximum head of nineteen feet; and Long and Pelican lakes, tributary by Pelican creek, from which the last of these lakes, about five miles in diameter, is separated by a low beach ridge of gravel and sand, through which its waters seep into the creek.

Southeast of Pelican lake are about a dozen others which occupy bowl-like hollows, without outlets, in the nearly level surrounding sand and gravel plain. Of these the largest is lake Edward, about two and a half miles in diameter. The origin of the hollows containing these lakes, with their bottoms twenty-five to fifty feet below the general level, will be considered in treating of this modified drift.

The most southwestern portion of this tract comprises Long, Round, and Hubert lakes, and the Upper and Lower Gull lakes, the last, which is the largest, being nine miles long and one to three miles wide, besides a score of smaller lakes, all outflowing by the Gull river, either with visible outlets or by percolation through the enclosing porous gravel and sand.

Topography. Two belts of prominently hilly morainic drift cross this district, rising in knobs, hills, and massive irregular ridges to hights 75 to 200 feet above the average of the adjoining country. The other parts of the district, comprising nine-tenths of its area, vary from a moderately rolling contour, with the highest tracts or crests of swells twenty-five to fifty feet, or sometimes more, above the depressions, to nearly flat expanses where no portions rise more than five to ten feet above the lowest, excepting that frequent hollows, from a quarter of a mile or less to five miles or more in length, are occupied by lakes. In the nearly level areas, which consist usually of stratified gravel and sand, the surface of the lakes is commonly ten to twenty feet below these modified drift plains, and their depths range from five or ten feet to fifty feet, or rarely more.

A mostly rather narrow and partially interrupted series of drift hills, correlated with the Leaf Hills moraine, extends north-northeasterly from the vicinity of Pillager for a distance of forty miles to the eastern part of T. 139–28, where it is intersected by the Mississippi & Northern railroad. Northwest of Sylvan Lake station, and along the west side of Gull lake, the hills of this morainic belt occupy

a width of one to two miles and rise 75 to 150 feet above these lakes. Through a distance of six or eight miles thence northward the moraine is interrupted, this being the southern part of its extent across a wide expanse of modified drift. Next the moraine is found typically developed in very bouldery low hills from the northeast corner of T. 136–29, northeastward, with a width of about a mile, to the south side of Whitefish lake. North of this lake it expands to a width of three or four miles, and holds this width onward, passing along the north sides of lakes George and Washburn, where it is especially conspicuous, to the headwaters of the Moose river, and thence continuing northeasterly to the Poquodenaw lake and mountain in northwestern Aitkin county. In the northeast part of T. 138–28, crests of this moraine rise to 1,450 or 1,475 feet, being the highest land in Crow Wing county close to its north boundary.

The other and more northern morainic belt, named the Itasca moraine from its prominence adjacent to the southern arms of lake Itasca, and upon a width of about ten miles southward, stretches across this district from west to east, generally forming a watershed between streams flowing to the north and south. It is intersected, however, by the Boy river and by the head stream of the Willow river. This belt forms the southwestern and southern shores of Leech lake, and its hills and broad, very uneven ridges occupy a width of ten to twelve miles thence southward. The road from Leech Lake Agency to Brainerd crosses the highest part of this moraine in a majestic white pine forest at an altitude of 1,500 feet above the sea, or about 200 feet above Leech lake. On the southwest. Ten Mile and Fourteen Mile lakes lie about 125 feet below this highest point of the road. From other high portions of this road a far-reaching view of the mostly lower but very unevenly hilly westward course of the moraine is obtained; while eastward some of the hills rise probably to 1,550 feet, being the highest land in Cass county. Fourteen Mile, Ten Mile, Woman, Wabado, and Little Boy lakes are situated in the southern part of this moraine, being mostly surrounded by its irregularly grouped knolls, ridges, and hills.

East of the Boy river this belt is less conspicuously and continuously developed. Its course is deflected to the northeast and then southward and eastward, making a re-entrant angle between the Bear and Vermilion rivers, where its hills rise about 200 feet above the marshy lowland that borders Mud lake. Ten to fifteen miles southeast and east from these hills, the Itasca moraine is well exhibited southwest, west, and north of Pokegama lake in Itasca county.

The northern third of this district, north of the Itasca moraine, is approximately level, the hights of Cass, Winnibigoshish, and Leech lakes being very nearly the same; but adjoining the north shores of Leech lake the highest swells

and massive drift ridges rise 75 to 100 feet. The average altitude of this part is 1,300 to 1,350 feet above the sea, being about 100 feet above that of the southern third or quarter of the district, from Whitefish and Cross lakes southward to the Mississippi and Brainerd and southwest to the Crow Wing river.

Elevations, Northern Pacific railroad.

From profiles in the office of S. D. Mason, engineer, and Richard Relf, assistant engineer, St. Paul.

	Miles from Duluth.*	Feet above the sea.
Brainerd, 138 miles from St. Paul,	118.5	1,209
Mississippi river, bed, 1,144; extreme low water (1874), 1,150; extreme high water (1866), 1,167; grade,	119.0	1,211
Depression, grade,	119.6	1,196
Baxter,	122.5	1,205
Summit, natural surface,	124.4	1,212
Gull river, bed, 1,165; water, 1,170; grade,	126.0	1,191
Gull River station,	126.3	1,191
Summit, natural surface,	128.2	1,210
Sylvan Lake station,	128.5	1,207
Pillager creek, bed, 1,172; water, 1,175; grade,	131.3	1,195
Pillager,	132.0	1,203
Wheelock,	137.0	1,214
Crow Wing river, bed, 1,205; water, low stage, 1,208; grade,	140.0	1,225
Motley,	140.5	1,227

Brainerd & Northern Minnesota railway.

From profile in the office of the Gull River Lumber Company, Minneapolis. For the portion of the branch of this railroad northwest of Gull lake, as operated for lumbering purposes during the year 1893, no profile is preserved. Distances are noted from the mill of this company, on the southeast side of the Mississippi about one and a half miles northeast of Brainerd.

	Miles from mill near Brainerd.	Feet above the sea.
At the mill, railroad grade,	0.0	1,189
Mississippi river, held by a dam one-third mile southwest, low and high water, 1,170–1,176; grade,	0.2–0.4	1,186
Siding on the west side; grade,	1.5	1,223
Summit, cutting 5 feet; grade,	1.9	1,233
Depression, grade,	2.9	1,209
Summit, natural surface and grade the same,	3.5	1,223
A nearly level grade, mostly 1,220 to 1,213, extends along the next seven miles.		
Lake Hubert water, 1,199; grade along its northern shore,	10.8–11.0	1,205
On the branch extending westward from lake Hubert, used for transportation of logs during 1893 (track laid in 1892 and taken up in 1894)—		
Nearly level grade,	11.2–11.8	1,220–1,224
Depression, filling 5 feet; grade,	12.2	1,213
Summit, natural surface and grade the same,	12.6	1,238
Leech lake road,	13.0	1,237
Depression, natural marsh surface, 1,198; grade,	14.3	1,202
Summit, cutting 9 feet; grade,	14.6	1,223
Depression, natural marsh surface, 1,196; grade,	15.0	1,200
Cut in drift, 15 feet deep; grade,	15.3	1,212
Gull lake, thoroughfare extending northward from the main lake at the same level, water, 1,196; grade,	15.7–16.1	1,202
On the main line of this railway, built in 1894, extending northward from lake Hubert—		
Depression, grade,	12.2–12.4	1,209
Summit, grade,	12.9	1,232
Outlet of the Cullen lakes, water, 1,196; grade,	13.7	1,209
Outlet of the Twin lakes, low and high water, 1,194–1,199; grade,	14.7	1,216
A very irregularly knolly surface reaches from the first of these streams along a distance of three miles northward.		

* Distances are by the new line of this railroad, passing through West Superior to Carlton, being 4.5 miles greater than by the St. Paul & Duluth railroad line, which was formerly used by this company.

	Miles from mill near Brainerd.	Feet above the sea.
Summit, grade,	18.5	1,285
Summit, grade, again at the same hight,	20.4	1,285
Depression, grade,	21.6–21.8	1,257
Hay creek, bed, 1,257; grade,	22.6	1,271
Summit, natural surface and grade,	24.1	1,288
Pine river, water, 1,271; grade,	25.9	1,279
Summit, grade (2 feet above the natural surface),	27.1	1,290
Norway creek (North fork of Pine river), water, 1,275; grade,	27.6	1,284
At Pine River postoffice, grade,	28.3	1,299
Summit, natural surface and grade,	33.0	1,350
Depression, grade,	34.5	1,326
Summit, natural surface and grade,	35.7	1,354
Twenty-four Mile creek, close below Pine Mountain lake, bed, 1,318; grade,	36.2	1,338
Summit, natural surface and grade,	39.4–39.6	1,353
Summit, natural surface and grade,	44.6	1,392
Boy river, the outlet of Fourteen Mile or Birch lake, bed, 1,373; grade,	45.3	1,389
Summit, cutting 6 feet; grade,	47.3	1,430
Depression at east end of Ten Mile lake, water, 1,378; grade,	49.0	1,391

Mississippi & Northern railroad.

From profile in the office of E. T. Abbott, engineer, Minneapolis.

	Miles	Feet above the sea.
Cross lake, stage of maximum capacity of the dam, 1,236.5; highest stage to which the lake is expected to be raised, 1,231; water surface at usual stage of flowage,	0.0	1,227
South end of railroad, at place of unloading logs into Cross lake,	0.0	1,253
Summit, cutting 7 feet; grade,	1.5	1,264
Trout Lake creek, bed, 1,230; water, 1,233; grade,	2.6	1,238
Nearly level grade,	4.3–5.0	1,318–1,322
Top of steep ascent from south,	7.3	1,426
Junction of Norway Lake branch,	10.2	1,470
On this branch—		
Summit, cutting 2 feet; grade,	11.0	1,481
Little Norway lake, head of the east branch of Norway brook,	13.4	1,400
Grade here, end of this branch,	13.4	1,404
On the main line northward—		
Summit, cutting 5 feet; grade,	10.8	1,494
Branch of Stony creek, in the east edge of sec. 36, T. 140–28, close east of Grass lake, water, 1,321; grade,	15.5	1,326
An irregular surface of morainic drift, with frequent knolls 20 to 30 feet above the intervening hollows, reaches thence to the Little Boy lake and Boy river.		
Depression, natural surface, 1,310; grade,	17.7	1,315
Deep cut of glacial drift, natural surface, 1,353; grade,	18.2	1,332
Little Boy lake, water, 1,309; grade,	18.9	1,312
Boy river, bed, 1,317; water (raised by a dam which flows Girl and Woman lakes), 1,324; grade,	23.0	1,327

Survey by the Great Northern railway company for a proposed railway line from Milaca to Brainerd, Leech lake and Fosston.

From profile in the office of N. D. Miller, engineer, St. Paul.

	Miles from Milaca.	Feet above the sea.
Northern Pacific railroad, about a half mile east of Brainerd,	50.6	1,206
Proposed railway grade beneath the Northern Pacific track,	50.6	1,185
Mississippi river, bed, 1,149; water, 1,155; grade,	51.6	1,176
Cut 50 feet deep, proposed grade,	51.8	1,180
Gilbert lake, water,	52.2	1,172
Narrows of Long lake, bed, 1,163; water,	57.1–57.3	1,198
Summit, natural surface and proposed grade,	58.1	1,224
Cullen lake, bed, 1,180; water,	64.8	1,198
Norway creek, bed, 1,275; water,	77.6	1,277
Narrows of Ten Mile lake, bed, 1,354; water,	98.4–98.6	1,378

Very knolly and hilly morainic drift reaches from Ten Mile lake to Leech lake and onward to Benedict creek.

	Miles from Milaca.	Feet above the sea.
Arm of Leech lake, bed, 1,272; water,	103.7–104.1	1,294
Summit, cutting 28 feet, to proposed grade,	109.1	1,380
Benedict creek, bed, 1,292; water,	112.2	1,295
Thence a smooth surface, largely tamarack swamp, extends forward.		
Kabecona river (outlet of Kabecona lake), bed, 1,295; water,	115.4	1,297
Summit, cutting 11 feet to proposed grade,	117.9	1,335
Kabecona river (flowing into Kabecona lake), bed, 1,301; water,	119.0	1,303
Kabecona lake, about	115–119	1,302

Mississippi and Crow Wing rivers, and other streams and lakes.

Determined mostly by United States engineers, in surveys for the system of reservoirs on the headwaters of the Mississippi; partly by railway surveys; and, in the case of lake Itasca, by J. V. Brower, commissioner of the Itasca State Park (to whose published altitude seven feet are here added, as required by the corrected elevation of the Great Northern railway at Park Rapids).

	Feet above the sea.
Lake Itasca,	1,464
Lake Pemidji,	1,355
Cass lake, ordinary stages,	1,300–1,302
Mississippi river at the mouth of Horn river,	1,298
Horn lake,	1,309
Lake Winnibigoshish, also Little Winnibigoshish lake, formerly	1,290–1,293
Lake Winnibigoshish, as raised by dam of reservoir system,	1,298
This dam is constructed with capacity to raise the lake to 1,304 feet; but it is not expected that it will be raised higher than 1,300 feet.	
Mississippi river at head and foot of small rapids three miles below Little Winnibigoshish lake,	1,288–1,287
Mouth of Leech Lake river,	1,279
Mississippi river at White Oak point,	1,276
At Mouth of Vermilion river,	1,273
Vermilion lake (previous to the construction of its dam, which raises this lake about six feet higher),	1,278
Mississippi river at mouth of outlet of Pokegama lake, formerly	1,270
Pokegama lake, formerly	1,271
Same, as raised by dam of reservoir system,	1,275
Head of Pokegama falls, formerly	1,269
Same, as raised by dam flowing Pokegama lake,	1,275
Foot of Pokegama falls, 900 feet from the last,	1,254
Head of Grand rapids, 3½ miles below Pokegama falls,	1,253
Foot of Grand rapids, ⅓ mile from the last, at the head of navigation of the upper Mississippi,	1,248
Mouth of Split Hand river,	1,236
Mississippi river at Aitkin, low and high water,	1,190–1,200
Mouth of Pine river,	1,177
Head and foot of Big Eddy rapids, as formerly, ½ mile long,	1,170–1,167
Head and foot of Island rapids, as formerly, 3,000 feet long,	1,164–1,162
French rapids, lowest stage of water, as formerly, between 3 and 4 miles above Brainerd, 4,000 feet long, about	1,159–1,154
Dam of the Gull River lumber company, about 1½ miles north of Brainerd, flowing the river back, over French and Island rapids, to the head of Big Eddy rapids, low and high water,	1,170–1,176
Mississippi river at Brainerd, low and high water,	1,150–1,167
Mouth of Crow Wing river, low and high water,	1,145–1,163
Chain of lakes along the head stream of the Crow Wing river –	
Crow Wing or Eleventh lake,	1,390
Tenth lake,	1,387
Ninth lake,	1,386
Prairie or Eighth lake,	1,385
Seventh lake,	1,382
Sixth lake,	1,379
Fifth lake,	1,378
Crow Wing river at Motley, low water,	1,208
Junction with the Mississippi river, low and high water,	1,145–1,163
Leech lake, formerly 1,293–1,295; as now usually raised by the dam of the reservoir system,	1,297
The maximum capacity of this dam is 1,299.5 feet; but it is not expected that the lake will be raised above 1,298.5 feet.	

	Feet above the sea.
Mud lake, on the Leech Lake river,	1,280–1,283
Portage lake,	1,299
Hight of land on the trail from Leech and Portage lakes to lake Winnibigoshish,	1,324
Steamboat and Duck lakes, northwest of Leech lake, about	1,297
Kabecona lake, about	1,302
Lake Benedict, formerly 1,295; as now raised by the Leech Lake dam,	1,297
Ten Mile lake,	1,378
Hight of land, summit of the Itasca moraine, on the road leading south from Leech Lake Agency to Brainerd, in the S. W. ¼ of sec. 19, T. 141–30, about 1½ miles northeast of Ten Mile lake,	1,500
Fourteen Mile creek, or Boy river, on this road at the mouth of Fourteen Mile lake, and having the same level,	1,375
North branch of Pine river at the crossing of this road, nearly at the same hight as Pine Mountain lake,	1,323
South branch of Pine river at the crossing of this road,	1,274
Hay creek, at crossing of this road,	1,238
South branch of Hay creek, at crossing of this road,	1,243
Lower Hay lake, formerly	1,225
This lake is now raised by the Pine river dam to 1,227 feet.	
Whitefish lake, formerly	1,224
Same, as now raised by the Pine river dam at the outlet of Cross lake,	1,227
Highest level to which it is expected that Cross, Whitefish, Trout, and other lakes may be raised by this dam,	1,231
Stage of maximum capacity of the Pine river dam,	1,237
Pelican lake,	1,211
Horseshoe lake, Mission, Silver, and Bass lakes, and lake Edward, east and southeast of Pelican lake,	1,210–1,200
Lakes Sibley and Mayo, about	1,205
Upper Gull lake, Gull lake, and lake Kilpatrick, held at the same level by a dam,	1,196
Lower, Middle, and Upper Cullen lakes, held at the same level by a dam,	1,200
Sylvan lake,	1,201
Round lake,	1,195–1,196
Lake Hubert,	1,199
Long Lake,	1,198–1,200
Red Sand lake, secs. 35 and 36, T. 134–29,	1,201
Gilbert lake, 2 miles north of Brainerd,	1,172
Boy lake, about	1,300
Upper Boy lake, or lake Ingadonah, about	1,308
Rice lake, on the Boy river, and Little Boy lake,	1,309
Wabado and Waupatoos lakes,	1,312
Girl and Woman lakes,	1,324
Little Norway lake, secs. 27 and 28, T. 139–28,	1,400
Big Rice lake, Willow river, estimated,	1,325
Little Thunder lake and Thunder lake held at the same level by a dam, estimated,	1,335
Lake Laura, estimated,	1,325
Lakes George and Washburn, estimated,	1,350
Crooked lake, estimated,	1,325
Mitchell, Eagle, Kego, and Fox lakes, T. 138–27, about	1,260–1,300
Lakes Emily, Mary, and Ruth, Little Pine river, southeast part of T. 138–26, about	1,275–1,300
Pine lake, on the Pine river, mostly in sec. 33, T. 137–27, about	1,200
Mouth of Pelican creek, about	1,195
Mouth of Little Pine river, about	1,185
Moose lake, secs. 10 and 15, T. 136–31, estimated,	1,350
Spider lake, west line of T. 137–31, estimated,	1,350

The range of altitude in this entire district is about 400 feet, from its lowest land, at the junction of the Crow Wing river with the Mississippi, which at the lowest stage of water is 1,145 feet above the sea, to the highest summits of the Itasca moraine south of Leech lake about 1,550 feet.

Average altitudes of various portions of this district, above the sea level, are estimated as follows: the northeastern part of Cass county in ranges 25 to 29, from lake Winnibigoshish and the Mississippi river to the south line of the 142d row of townships, coincident approximately with the south side of Leech lake and including about half of the area of this lake, with a total land and water area of about 665 square miles, approximately 1,320 feet; the remaining ranges 30 and 31 in the northwest part of this district, from the north line of Cass county, crossing Cass lake, to the same southern limit of the south line of T. 142, comprising an area of eight government townships or about 288 square miles, with the western half of Leech lake in its

southern portion, approximately 1,325 feet; next on the south, the belt formed by Ts. 141, 140 and 139, comprising an area of twenty-one townships or about 756 square miles, in which are the greater part of the Itasca moraine and the northeastern part of the Leaf Hills moraine in their development through this district; besides considerable tracts of the ordinary moderately undulating or nearly flat glacial and modified drift, approximately 1,390 feet; the northwestern part of Crow Wing county, extending from its north boundary, adjoining the belt last noted; south to the Mississippi river, about 610 square miles, approximately 1,265 feet; and the southern part of Cass county, between Crow Wing and Wadena counties, and reaching south to the Crow Wing river, about 690 square miles, approximately 1,300 feet.

The mean elevation of the part of Crow Wing county mapped and described in this chapter, as already noted, is about 1,265 feet; and the mean elevation of Cass county, so far as it is here mapped and described, is about 1,335 feet. The northwestern twelve townships, or about 432 square miles, of Cass county, which lie north of Hubbard county and are included with that county for mapping and description, have a mean elevation of about 1,425 feet. With this portion of its area, the whole of Cass county has a mean hight of 1,350 feet, very nearly.

Soil and timber. Nearly the entire area of this district belongs to the great forest region of northern Minnesota. Its only tracts of prairie are very small, occurring on the modified drift plains which adjoin the Mississippi and Crow Wing rivers on the southern boundary of the district.

Across the southern half of this area are large expanses of the gravel and sand deposits which constitute the greater part of our modified drift, and, in less extensive plains, the same formation also borders the Big Rice lake and covers much of the country thence northward to lake Winnibigoshish and westward along the Mississippi to Cass lake. These plains are not generally quite flat, but more commonly undulate in long slopes and broadly rounded swells, with crests five to twenty feet above the depressions. In many places, too, the same class of drift, with frequently an increased proportion of gravel and large water-worn cobbles, forms low knolls and irregular ridges or small plateaus, twenty-five to fifty feet in hight above the general level. All these modified drift deposits have a more fertile soil than would be found in regions where limestone is absent from the drift gravel and sand. Often large tracts of the nearly level plains have a rich dark soil six inches to a foot deep, which in cultivation bears good crops. Other portions of the modified drift, including most of its knolly and ridgy land, have a less productive soil, and are worth more for the growth of firewood and timber than for agriculture.

Tracts of till, or intermingled clay, sand, gravel, and boulders, form more than half of the district. These include the greater part of its morainic belts, where the very uneven contour and abundance of boulders are commonly sufficient to forbid the use of the land for cultivation, though it may well be cleared for pasturage. The hilly moraines may be estimated to include, however, no more than a third of the till areas; and the remaining portions, with moderately undulating or rolling surface, comprising probably two-fifths of the district, are very valuable agricultural lands, needing to be cleared of their timber to make farms, but having a soil unsurpassed in fertility, excellent conditions of drainage, and adaptation to all the crops of this latitude.

The modified drift areas are generally wooded with jack pine and Norway or red pine. The second and much the more valuable one of these species occurs often in beautiful groves, with no undergrowth of shrubs, the reddish-brown trunks being limbless to hights of thirty to fifty feet. On areas of till the jack pine is rare or altogether absent, and the red pine grows intermingled with the white pine, or the latter species sometimes forms a thick forest growth alone. It is more frequently intermingled with deciduous trees; and these also form extensive tracts of woods with no evergreen species. The principal deciduous forest trees are the basswood, maples, species of ash, elms, oaks, ironwood, the canoe birch and yellow birch, cottonwood and poplars. Less frequent are the box-elder, wild black cherry, two species of mountain ash, the Juneberry, hackberry, butternut, and red cedar. In swamps and on higher moist lands are the tamarack, spruce, balsam fir, and arbor-vitæ, the last usually called white cedar.

Several of our trees reach their northern limits in this district, including the river maple, box-elder, corky white elm, hackberry, butternut, swamp hickory or bitter-nut, white oak, swamp white oak (Quercus bicolor), black and red oaks, American hornbeam (Carpinus caroliniana), and the cottonwood.

Among the shrubs and small trees of thickets, and of the forest undergrowth, are the prickly ash, staghorn and smooth sumachs, the riverside or frost grape, the Virginian creeper, alder-leaved buckthorn, and the climbing bittersweet; the striped and mountain maples; the wild plum, pin or bird cherry, and choke cherry; the western Juneberry (called "Saskatoon" in Manitoba); wild gooseberries and currants; numerous species of cornel, honeysuckle, and arrow-wood or viburnum, the most important of the latter being the cranberry-tree or bush cranberry; dwarf blueberries, very plentiful and much gathered for city markets; leather-wood; hazel-nuts of two species; the low birch (Betula pumila), the common alder, and several species of willow; the creeping juniper (Juniperus sabina, var. procumbens), and the American yew or ground hemlock (Taxus baccata, var. canadensis). A great variety of herbaceous plants, many of them bearing attractive flowers, is also found on marshy and boggy ground, in openings of the woodlands, on the sunny slopes of hills, on the scantily wooded and often grassy modified drift plains, and on river banks and lake shores.

GEOLOGICAL STRUCTURE.

Archean and Taconic rocks. Very few rock outcrops occur in this district, being known in only two localities. It is therefore difficult to state what are probably its bed rocks next underlying the glacial drift on nearly the whole of its area. The Archean granite and gneiss, and the associated rocks, of Taconic age, forming the Mesabi iron range, which outcrop at the falls of Prairie river, at Pokegama falls, and in other places not far east of the northern part of the district, doubtless continue westward beneath the drift to the Boy river, on which rock exposures have been reported by E. W. and G. H. Griffin, and by H. V. Winchell, all several years ago and probably referring to the same place. Mr. G. H. Griffin, from recollection of his surveys and cruising, thinks that a considerable ridge of rock, at least several rods in extent, is passed in descending the Boy river about one or two miles below the mouth of Boy lake, in the north edge of T. 142-27; but the lithological character of this outcrop has not been ascertained.

The other locality of rock outcrops is in T. 134–32, the most southwestern township of Cass county, about eighty miles southwest of Pokegama falls, and nearly sixty miles south-southwest from Boy lake. The area of frequently outcropping rock at this locality, consisting of Archean granite or syenyte with diabase dikes, reaches about a half mile from south to north, and has a width of twenty to forty rods. It is mostly in the E. ½ of the N. E. ¼ of section 28, and extends north into the southeast part of the S. E. ¼ of section 21, and perhaps also beyond the lines of these into the adjoining sections 22 and 27 on the east. These outcrops in their southern part have a hight one to three feet, and in their middle and northern part five to eight feet, above the general surface of moderately undulating drift, being twenty to forty feet above the Crow Wing river, which lies about three-fourths of a mile to the southwest. The only considerable elevation in this vicinity is a hill of glacial drift, extending a quarter of a mile from north to south, situated a short distance east of these ledges, in the west edge of the N. W. ¼ of section 27. This rises forty to fifty feet above the rock exposures, and about seventy-five feet above the extensive marsh at its east side. Mainly the surface of this hill, as of the surrounding region, is sand and fine gravel, but boulders of granite up to five feet in diameter are found sparingly at its top and on its sides.

The greater part of the rock exposed here is gray granite, rather fine-grained, containing both white and flesh-colored feldspar, and a greenish mineral, probably epidote, which last is sometimes most abundant in streaks or veins, up to two inches in width. Rarely two or three of these veins are seen within a foot, giving the rock a somewhat schistose structure. Mica is generally absent or very scanty, but it occurs to some extent in the central part of the area.

Two wide dikes of dark, tough, massive diabase were noted here. One of these, near the south end of the area, is visible for an extent of twelve or fifteen rods, being fifty to sixty feet wide. The line of contact with the granite on the northeast side of this dike is very distinct and sharply defined along its exposure two or three rods in extent, bearing S. 50° E. At the second dike, near the north end of these exposures, both lines of contact with the enclosing granite are visible at many places along a distance of fully 200 feet, bearing S. 70° E., which is the course of a conspicuous system of joints in the granite. The width of this dike is thirty feet. From its northern side a branch of irregular course and varying from two feet to three inches in width, reaches forty feet northerly, as shown in figure 8. At one point seven or eight feet from the main dike an offshoot from this branch is seen extending several feet with a width from one inch to only an eighth of an inch. The aspect of this dark eruptive rock is nearly the same in all portions; its line of contact, wherever exposed, is very sharply defined;

and the granite adjoining shows no notable difference from that at a greater distance. Some portions of the granite here may be found valuable for quarrying. (Consult also sixth annual report, p. 46, for Prof. Winchell's observations on this rock.)

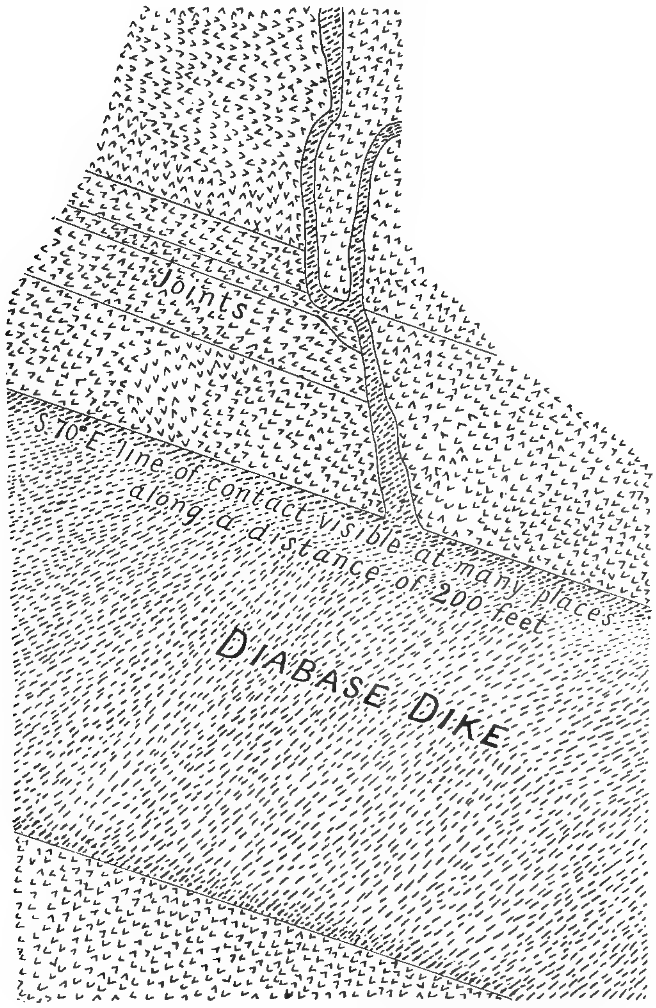


FIG. 8. DIKE OF DIABASE IN GRANITE, SEC. 28, T. 134-32.
Scale, 40 feet to an inch.

In its peculiar lithologic character, as containing the green mineral thought to be epidote, the granite or syenyte of this locality shows a noteworthy resemblance to outcrops in two other localities, situated in Ward township, Todd county, and in Ashley, Stearns county, distant from this place respectively about fifteen and forty-five miles south-southwest.* Although there are no intervening outcrops, it seems to be a reasonable assumption that these exposures represent a continuous belt or broad area of this rock, evidently an originally deep-seated igneous formation which is now exposed by denudation, and which, previous to the Cretaceous submergence of this region, formed the surface throughout this distance of nearly fifty miles.

* Geology of Minnesota, vol. ii, pp. 452, 569.

Toward the north and northeast, the next exposures of granite, perhaps to be correlated with the foregoing as contemporaneous or nearly so, are those which are found forming the high long ridge called the Giant's range. The relations of that granite belt to the adjoining Archean and Taconic formations show that the intrusion of the Giant's range granite took place after the deposition of the Keewatin or upper division of the Archean, but before the deposition of the Animikie series or lower division of the Taconic system. Subsequent to that granite intrusion, deep and widely extended denudation, producing agreat unconformity between these systems, had laid bare the granite slopes of the Giant's range against which the iron-bearing Animikie strata were deposited. The thickness of overlying rock requisite to give the granitic texture of the outcrops on the Giant's range and in Cass, Todd, and Stearns counties, was probably at least several hundred feet. This erosion interval may be regarded as the division between the Archean and Paleozoic eras, relegating the Giant's range granite and probably also the granite or syenyte of southwestern Cass county and of the two localities noted farther south to the closing stage of Archean time.

Aside from the granitic belt which probably underlies the drift and Cretaceous beds from the northeastern to the southwestern limits of this district, we have very scanty means for conjecturing what Archean formations would be encountered by borings upon its larger southeastern and northwestern portions. The observations of gabbro in Moran, northeastern Todd county,* and of crystalline schists, referable to the Keewatin series, in T. 130–30, Morrison county,† not far south of the Crow Wing river, in connection with the extensive development of these rocks on the east in Carlton county and at Duluth and northward, lead to the belief that considerable areas of intrusive basic rocks, and probably larger areas of Keewatin schists and slates, would be found next below the Cretaceous in the southeastern part of this district, while between their north side and the granitic belt we should have the Animikie slates, iron-bearing rocks, and quartzyte. Westward it is quite as probable that the granite would be found continuing to the limits of the district.

Cretaceous beds. Next beneath the glacial drift upon the greater part of this area are probably Cretaceous strata, chiefly shales, similar to those found sparingly outcropping in the valleys of the Mississippi and Sauk rivers in Morrison and Stearns counties. Wells sufficiently deep to pass through the drift to the Cretaceous have not been bored in this district, nor in closely adjoining portions of the state; but so many such sections have been found by wells in southern and western Minnesota, going various depths to a maximum exceeding 500 feet in Cretaceous shales and

* Geology of Minnesota, Final Report, vol. ii, p. 568 (called dioryte); Twenty-first Annual Report, for 1892, pp. 114, 115.
† Final Report, vol. ii, p. 601; Twenty-first Annual Report, p. 113.

beds of sandstone, before reaching granite, gneiss, or other rocks below, that we may reasonably infer the existence here of the same Cretaceous beds with similar thickness.

The grand topographic features of the country in which the Mississippi has its sources, from lake Itasca east to Leech lake, seem suggestive of forms produced by preglacial stream erosion, probably in Cretaceous beds, now heavily mantled by the glacial and modified drift. Such, for example, I think to have been the origin of the wide, deep valleys occupied by the head stream of the Mississippi in its course north from lake Itasca and by the La Salle, Hennepin, and Schoolcraft rivers, its successive tributaries from the south between lakes Itasca and Pemidji. Again, the deep basin of Leech lake, with its numerous arm-like bays, one of them having a maximum sounding of 100 feet, may be probably attributed to preglacial stream excavation by a river and its branches, other portions of the same valley being filled and concealed by the thick drift deposits.

Fragments of lignite, doubtless derived by glacial erosion from thin layers of lignite in Cretaceous beds of the district or of the country northward, are occasionally found in the gravel of lake shores, as of Winnibigoshish and Leech lakes, and in the till, as in digging cellars and wells.

Glacial and modified drift.

No deep wells penetrating to the formations underlying the drift have given measures of its thickness in this district; but it is probably a somewhat uniform mantle from 100 to 200 feet deep, as it is ascertained to be generally in other parts of the central and western two-thirds of Minnesota. The greatest thickness is doubtless attained along the courses of the moraines, whose hilly accumulations in some instances add 100 to 150 feet or more to the average drift sheet. If the knolls and hills of any part of the moraines here were levelled, however, upon the whole width that is more or less occupied by them, the amount so added above the surface on either side would range probably from ten to fifty feet.

An estimate of the relative mass of the till, or true glacial drift, and of the modified drift, transported and deposited by water immediately after its release from the ice-sheet, although based on very meager data in respect to the thicknesses of these formations, may be ventured as approximately in the ratio of three or four to one, for this district. Their ratio in area is nearly as three to two; but upon considerable portions of the tracts of modified drift it is thin and is underlain by a greater depth of till. Superficially, too, the morainic belts contain more modified drift than would probably be seen in deep sections. Conversely, however, the areas of till usually consist of the same deposit to great

depths, with only thin layers or seams, often water-bearing, of the modified drift gravel and sand. Both in area and in mass this division of the drift is more largely represented here than in this state as a whole.

Extending these estimates to embrace all of Minnesota, I think that its till and modified drift hold an areal ratio of twelve or fifteen to one; and that their respective volumes are as fifteen or twenty to one. But in and near the principal towns and cities, which are situated usually on rivers, and in riding along the railroads, which select valleys and plains so far as possible for their routes, the casual observer would infer a much larger relative amount of modified drift. If the mean thickness of all the drift in Minnesota is about 100 or 125 feet, as seems probable when its thick western development offsets its thinner deposits northeastward, we may estimate the part which consists of water-stratified gravel, sand, and clay, to average between five and ten feet.

Till. In this district the boulders of the till have been transported prevailingly from north to south, in less proportion from northeast to southwest, and very scantily from northwest to southeast. They are mostly Archean granites, gneisses, and crystalline schists. Magnesian limestone boulders, such as abound in the drift generally through all the western half of this state, derived from limestone areas in Manitoba with outcrops near Winnipeg and northward, are rarely found in the drift of Cass and Crow Wing counties. They occur plentifully about Red lake, but are absent or very rare thirty to sixty miles farther southeast about Cass, Winnibigoshish and Leech lakes.

Mr. William E. Seelye, of Brainerd, to whom I am indebted for many valuable notes of his observations as a land and timber examiner throughout this district, informs me that he found a mass of limestone about twenty-five by twenty by twelve feet in size, lying on a low ridge of the principal Leaf Hills moraine near the east side of the N. E. ¼ sec. 29, T. 137-28, about a mile south of Whitefish lake. The dip of this exceptionally large drift block was about 30° westward. Several other limestone slabs up to five or six feet in length were seen within a short distance southwest.

The proportion of boulders and coarse gravel in the till here is greater than the average for the southern and western three-fourths of Minnesota, but notably less than for most of its portion northeastward. In proceeding from east to west across these counties and onward to the Red River valley, one observes, in the comparison of sections of the till, a gradual decrease of the boulders, gravel and sand, and a corresponding increase of the clay. This is due to the westwardly increasing proportion of the till which is derived from the erosion of Cretaceous beds, chiefly shales.

On the shores of all the larger lakes, wherever they consist of till, many boulders are left by the wave erosion of the finer portions of this deposit, and often these boulders are piled as a wall along the foot of the eroded slopes of till to the hight of five to eight feet above the water level. During the building of the Winnibigoshish and Leech lake dams, a steamboat was used to tow rafts of these boulders from distant parts of the lake shores to the sites of the dams for use in their construction. The largest boulders are rarely ten to fifteen feet in diameter; but more than ninety-nine per cent. of them are of smaller sizes.

The deepest section of the till learned for this area or its borders is that of Mr. J. T. Frater's well, about a mile southeast of Brainerd, on the Mille Lacs road in the N. E. ¼ sec. 6, Long Lake township. This well, which has a total depth of 112 feet, was in till, yellowish near the surface and dark bluish below, to the depth of 100 feet. Next were stratified sand and gravel, from which water rose to twenty-six feet below the surface. The till could be picked to the depth of only one or two inches by a heavy blow.

Terminal moraines. An earlier part of this chapter, treating of topography, has noted the width, extent, and contour of the two principal knolly and hilly belts of morainic drift which cross this district. The more southern and narrower belt extending from Pillager northeast and east into the northern part of Aitkin county, is regarded as contemporaneous and continuous with the Leaf Hills moraine. In Otter Tail county, where this moraine, blending with the Fergus Falls moraine, forms the prominent Leaf hills, a later and subordinate morainic belt,

branching from that of the Leaf hills, at the northeastern end of their curving course, extends thence northward by the east side of Rush and Pine lakes to unite again with the western and main division of the Leaf Hills moraine in southern Becker county, there forming the conspicuous Toad mountains. Likewise, in northwestern Crow Wing county and southwestern Cass county, this moraine is twofold, its separate portions spreading, as in Otter Tail county, to a maximum distance of fifteen or eighteen miles apart.

The eastern and older part of the Leaf Hills moraine, here accumulated on the southeast side of this waning lobe of the ice-sheet, has been noted in its course from Pillager and the northwest side of Sylvan and Gull lakes to Whitefish lake, the north side of lake Washburn, and onward to the Moose river on the east line of Cass county and to the Poquodenaw mountain in Aitkin county. The western and later subordinate moraine, correlated with the foregoing as together equivalent with the Leaf Hills moraine, runs from Gull lake northwesterly as a belt of moderately rolling or in portions somewhat hilly till, several miles wide, to Moose and Spider lakes, and thence north by the west side of Pine Mountain lake to unite with the broad Itasca moraine on the south side of Ten Mile lake.

Next west of Pine Mountain lake this moraine occupies a width of about six miles and rises 50 to 125 feet above the lake, with very irregular contour, often in steep slopes and enclosing here and there frequent large hollows without outlets. On the road from Park Rapids to Hackensack, it has a width of one and a half miles, lying in sections 20, 29, and 28, adjoining the west side of Jack Pine lake. Its material there is till, containing plentiful boulders and forming ridges fifteen to fifty feet above the enclosed hollows and lakelets. It is distinguished by being timbered with large white pines; whereas all the remainder of the country traversed by this road bears only jack pines and occasionally Norway or red pines, its material being modified drift, mostly in plains but near to the moraine somewhat broken.

The more northern and broader Itasca moraine has a magnificent development in its course from west to east through Cass county, passing south of Kabecona, Leech, Boy, and Mud lakes. On the road from Hackensack to Leech Lake Agency, the traveller passes first over about a mile of nearly level sand and gravel, bearing jack pines, beyond which the next three miles, to the shore of the eastern arm of Ten Mile lake, are typically morainic till, in countless small knolls, ridges, and hills, often enclosing hollows without outlet. The highest land here crossed is about 1,475 feet above the sea, or 100 feet above Fourteen Mile and Ten Mile lakes. As the timber there is scanty, this high land affords an extensive outlook westward over the lower portions of the moraine about these lakes and northwesterly toward lake Kabecona.

Abundant boulders occur of all sizes up to five feet, and a few are larger, to ten feet or more in diameter. Continuing northward, similar morainic till, but with less broken contour, extends to a northern boundary about a mile south of the Agency. Portions of it are well wooded with white pine, including its maximum hight of 1,500 feet above the sea. Its northern slope, descending somewhat gradually 200 feet in about six miles to the level of Leech lake, is interspersed with occasional small lakes which lie twenty-five to fifty feet below the road and average of the adjoining land. A prevailingly hilly surface, often with crests 50 to 100 feet above neighboring hollows and lakes, characterizes this morainic belt eastward by Woman, Wabado, and Little Boy lakes, and thence northeast by the headwaters of Bear and Vermilion rivers, to Sugar and Pokegama lakes and the Mississippi river in Itasca county.

Kames, eskers, and plateaus. During the departure of the ice-sheet the streams of its melting often deposited in their ice-walled channels thick accumulations of gravel and sand that had been washed away from the surface of the ice on which much drift, previously englacial, had become exposed by the gradual ablation. The boulders of this drift and much of its finer material remained on many areas of the thinned ice-sheet and were allowed to fall loosely as the superficial part of the till. But other portions, such as the rains, rills, and small and large streams of the dissolving ice-fields were able to transport, ranging from coarse gravel to the finest silt and clay, were borne away by the running waters. Flowing near their mouths in cañons of ice, with slackening currents because of the change from steeply descending courses on the ice-sheet to the less inclined land surface, the streams there deposited between the enclosing ice-walls much bedded gravel and sand, which after the disappearance of the ice were left as knolls, mounds, and sometimes long ridges called kames. Along the morainic belts short streams often formed such knolly and hillocky deposits over extensive tracts. They also occur, though less plentifully, in many other localities throughout the areas both of the ordinary moderately undulating or rolling till and of the nearly level modified drift.

Closely allied with these short kames, and here included under this name, are more prolonged sand and gravel ridges which were built up along the courses of the ice-walled streams for some distances above their mouths, probably growing in length from south to north as the front of the ice-sheet retreated. These longer modified drift ridges are now distinguished by some glacialists from the preceding under the name of *eskers* or *osars*, but the term kame is distinctively applied to these ridges by the reports of this survey, as it was earlier so used. Occasionally in this district a single kame extends a half mile to one mile or more. Often knolls and very short ridges are associated with them; and the two structural classes of modi-

fied drift deposits, intermingled or in alternation, are sometimes traceable in a series several miles from south to north.

The most noteworthy series of short knolls and kames observed in this district borders the Mississippi on its northwest side at Brainerd and for a distance of about three miles up the river, terminating in Ahrens hill. Where it is intersected by the Northern Pacific railroad, the width of this rolling gravelly belt is about a half mile; its crests are fifty to seventy-five feet above the river and ten to thirty feet above the hollows which separate the knolls and ridges; and from its western side a sand plain, nearly level with the mean hight of the kame belt or fifty feet above the river, extends westward. Following this belt northeasterly, it is found to be developed as a continuous kame of variable hight, mostly with steep slopes and rounded, sometimes narrow, crooked crest, in its most northern mile. An old road there runs along the crest, from the dam and bridge two miles above the city to the house of Mr. Charles Ahrens and over the top of the highest part, known as Ahrens hill, to its northern base.

The material of this kame is interbedded coarse and fine gravel and sand, the largest cobbles, mostly well waterworn, being about a foot in diameter. Its hight above the Mississippi river on the east and lake Gilbert on the west ranges from sixty feet in its lowest portions to 175 feet at the culminating point, about a quarter of a mile north of Mr. Ahrens' house and forty feet above it. On the southern slope and gently declining western flank of this higher part of the ridge Mr. Ahrens cultivates several acres, obtaining good crops of the ordinary farm staples, besides strawberries, raspberries, and other small fruits and garden produce. Descending the rather steep northern slope of Ahrens hill, I noted three or four boulders, the two highest, close to the top, measuring each about two feet, and another halfway down about five feet in diameter. These boulders, doubtless brought by ice-rafts and now lying partly imbedded on the surface, were the only rock masses too large for transportation by stream currents seen on this kame or elsewhere along the kame and esker series of which it is a part. The northern end of the series is abrupt, so that, in the view from the north, Ahrens hill is seen to rise from an approximately level sand and gravel plain of great extent whose surface is sixty to seventy-five feet above the river and lake.

Into the eastern part of Pine Mountain lake a narrow and low kame, five to fifteen feet above the water level, projects to a distance of about a half mile from the main shore. It is covered with Norway pines.

Another noteworthy though low kame is reported by Mr. H. V. Winchell as observed by him during land examinations in the year 1883, extending from south to north, along the west side of lake Laura, through the west edge of sec. 6,

T. 140–26, and the east part of secs. 36 and 25, T. 141–27, thence curving to the northeast and east, with a total length of nearly four miles. This is mostly a narrow ridge of sand and fine gravel, rising ten to twenty-five feet above the lakes, swamps, and hay meadows on either side, and measuring usually three to six rods in width. A road used by the lumbermen in teaming hay extends some two miles along its top.

When broad indentations or embayments of the retreating ice-front were formed at the mouths of the glacial rivers and their supply of modified drift was abundant, the deposits widened from the small and narrow kames and knolls to plateaus of stratified sand and gravel, varying in width up to one or two miles. An example of these accumulations is found on the east side of the Upper Gull lake, the surface of the plateau being fifty to sixty feet above the lake. Five to eight miles farther north, in the northeastern part of T. 136–29, a more extensive plateau, known as the Adams plain, fifty feet above lake Sibley on its southwest side, stretches thence to the northeast corner of the township, where it overlies the southwestern end of a prominently hilly belt of morainic till, with many large and small boulders, that reaches northeast to Whitefish lake. The places of Upper Gull lake and lake Sibley were filled by unmelted portions of the waning and receding ice-border, while the sedimentation alongside was rapidly amassing the plateaus.

Modified drift plains. Far the greater part of the modified drift was spread somewhat evenly on the land area close in front of the retreating ice, and forms nearly flat plains or only slightly undulating or rolling tracts, with their swells usually five to fifteen feet above the depressions, to which the descents are by long and gentle slopes. These plains cover large portions of Crow Wing and Cass counties. From the mouth of the Crow Wing river their expanse, forty to sixty feet above the Crow Wing and the Mississippi and ten to forty feet above the lakes which occupy its depressions, extends thirty miles, with a width of ten to fifteen miles, northeast and north to the Pine river and Cross and Whitefish lakes. Nearly intersected by the narrow Leaf Hills moraine, the same expanse, passing over low portions of this belt, continues northwestward twenty-five miles, with an average width of ten miles, to lakes Ada and Hattie, Ponto and Pine Mountain lakes, and to the mouths of Fourteen Mile lake and Jack Pine lake, at the heads, respectively, of the Boy and Pine rivers.

Again, separated from the foregoing by an irregular north to south belt of till, which has numerous outliers within the general modified drift tracts, similar extensive sand and gravel plains stretch from south to north on the west border of Cass county, along the east side of the Crow Wing river to its sources in the series of eleven lakes, lying mostly in Hubbard county, through which it flows.

Less extensive plains of modified drift, from a mile or less to ten or fifteen miles in length, often with half or two-thirds as great width, are interspersed here and there with the till areas upon all the northern half of Cass county, excepting the Itasca moraine. These sand and gravel tracts adjoin the Big Rice lake, lake Laura, Boy and Mud lakes and Winnibigoshish and Cass lakes. They have less development around Leech lake, whose shores are prevailingly till.

Most of the plans here described consist of gravel and sand to great depths, enclosing few or no layers of clay. The streams flowing away from the ice-sheet soon deposited these beds. The finer silt and clay, on the other hand, which must have been nearly equal in volume with these coarse beds, were borne forward down the valleys to the slower flowing lower courses of the rivers. These sediments in the Mississippi and Missouri valleys contributed to the loess, to the Port Hudson clays of the broad bottom-lands far south of the modified drift sand plains, and to the mud of the fast extending Mississippi delta. But in some places along the upper course of the Mississippi, exceptional deposits brought into the main valley by its tributaries, or other conditions of uneven sedimentation, led to the ponding back of the water or to its diversion into still lagoons outside the course of the river's current, whereby so tranquil conditions were provided that fine silt and clay beds, sometimes of considerable thickness, were laid down. Such beds are revealed by deep well borings beneath the gravel and sand plain on which Brainerd is built.

The well of the electric power house at the north end of the Brainerd street car line is 107 feet deep, passing through sand to a depth of seventeen feet from the surface; then, finer quicksand, eleven feet, with very abundant water in its lowest two feet; and stratified clay, containing no gravel nor boulders, seventy-nine feet; to sand at the bottom, from which water rose about seventy feet. The water brings in fine sand, which has caused much trouble by filling the pipe.

A third of a mile southward from this locality, the clay bed at the Koop Brothers brickyard is covered by twelve feet of sand, and has a thickness of seventy-three feet to the underlying sand.

About two miles distant to the southwest, on the southern limit of the city of Brainerd, Mr. Adam Brown has a well forty-eight feet deep, which was bored in June, 1892. Its section in descending order was sand and fine gravel, twenty feet; quicksand, two feet; and dark gray clay, twenty-six feet (only one-third as thick as farther north); to sand, from which water rises with a powerful flow to the surface, but will rise when confined in the pipe only two or three feet higher. It is the only artesian well of this city and all the surrounding country. This well, cased with two-inch pipe, flows at the rate of twenty-five gallons per minute. The water at first brought up much very fine sand, but soon flowed clear; and its rate of flow during the first year showed an increase rather than diminution. It is of excellent quality for drinking and cooking, deposits no iron rust, and is less hard for use with soap in washing than the water of the ordinary shallow wells. Its temperature is 44.° The surface at Mr. Brown's, on the northern verge of a ravine tributary to the Mississippi, represents approximately the general level of the plain in its vicinity, but is indeed some five to eight feet lower; and it is probably ten or fifteen feet below the plain at Brainerd depot, and somewhat more below the well and brickyard previously noted.

As originally deposited, the clay and overlying sand were continuous across the present channel of the Mississippi, which has since been cut by the river. The bed of this channel is somewhat above the underlying sand, which, therefore, has no discharge here for its water, excepting by this artesian well and perhaps by springs which may rise through crevices or joint planes of the clay. The ravine passing Mr. Brown's house and well has a small stream fed by many springs, one of the largest of which is about a half mile east. These, however, probably flow from the overlying sand at its plane of junction with the clay.

Kettle-holes and lake basins. In some places the sand plains of this district are indented or pitted by frequent hollows from a few rods to an eighth of a mile or more in diameter, round, oblong, or of irregular forms, sinking fifteen to twenty-five feet below the general level of the otherwise nearly flat surface. These bowl-like depressions, known as *kettle-holes,* were observed in abundance on the line of the Brainerd & Northern railroad in secs. 28, 21, and 20, T. 135–28, on the central part of the area partially bounded by Long lake and lakes Edward and Hubert. They differ only in size from the large depressions of these plains, up to several miles in diameter, which extend below the plane of saturation and consequently are occupied by the many small and large lakes. Some of these lake basins sink fifty to

seventy-five feet or more below the general level, and their water surfaces are five to twenty feet below the same level. Among the lakes of this district which are wholly or in large part enclosed by modified drift plains, I learned the reputed maximum depths of the following: Gull and Long lakes, each about eighty feet; lake Gilbert, forty feet; Pelican lake, fifty feet; and Cross and Whitefish lakes, about forty feet; Boom lake, at J. J. Howe's saw and planing-mills in the south edge of Brainerd, about thirty rods in its maximum diameter and said to be thirty feet deep, extending lower than the bed of the Mississippi river, with which it is connected by a little strait, is a very curious and interesting, although small, example of this class of lakes.

Where lake basins are wholly or mainly surrounded by till areas, like Leech lake, they may be ascribed to irregularities in the deposition of the drift due to its being eroded here and heaped up there by the fluctuating action of the ice-sheet. In the case of the kettle-holes and lakes enclosed by stratified drift, however, we must suppose that the spaces thus left empty were filled by unmelted remnants of the departing ice-sheet while the deposition of the adjoining sand and gravel beds took place from sediment-laden floods. In the smallest kettle-holes insular ice masses of only a few rods diameter stood out first as peninsulas and finally were cut off from the receding glacial border; but for the occupation of the lake basins some of these ice masses were miles in extent. The adjoining deposition was very rapid and was practically completed in each instance before the ice mass occupying the hollow was melted.

Chains of lakes. The lake basins which were left unfilled while deposition of the modified drift went on all around are occasionally arranged in series or chains. Such are Sylvan, Gull, and Upper Gull lakes, with lakes Mayo and Sibley, forming a series about nineteen miles long from south to north. Another series, through which the Pine river flows, comprises Cross, Rush, and Whitefish lakes, reaching, if we add also the Hay lakes, about ten miles from east to west. Again, the series or chain of Pine, Daggett, Eagle, Mitchell, Crooked, Lawrence, and Leavitt lakes, through which Daggett brook flows, extends fifteen miles from southwest to northeast. In a more general view, however, these three series may be very properly regarded as forming together a single chain of seventeen lakes, individually ranging from one to nine miles in length, and together reaching about fifty miles from south to north and northeast. These lakes are intimately related with the principal belt of the Leaf Hills moraine, for they mostly lie close alongside it, but northeastward from Whitefish lake are a few miles in front of it.

During a stage of the glacial retreat uncovering the southeastern part of this district, many lakes, mostly enclosed partly or wholly by modified drift, were formed,

until the ice rested or somewhat reädvanced in its accumulation of this belt of hilly morainic drift. Next, after a further retreat of five to ten miles northwestward, another stage attended by the formation of many lakes ensued, the more southern of which, from lakes Ada and Hattie to Pine Mountain lake and upon an extent of a half dozen miles thence northward, are entirely or partially enclosed by the stratified gravel and sand deposits. In this tract, however, a clearly consecutive order of the lakes is not discerned.

Another very notable chain of lakes is found along the head stream of the Crow Wing river, and is continued northeasterly to Leech lake. This chain comprises the Fifth to the Eleventh of the Crow Wing lakes, reaching thirteen miles from southwest to northeast, the last being known preëminently by that name of the river of which it is the farthest source. These lakes are bounded by areas of the modified drift which usually rises on each side with terrace-like steepness to plains forty to sixty feet above the lakes. Following the same course onward, we pass a large slough or marsh, then a land interval for one and a half miles, and then a succession of four lakes, the last two toward the northeast, respectively about two miles and one mile long, to the West bay of Leech lake, which in the continuation of the same line, has the extraordinary depth of 100 feet. These four lakes are comprised within the Itasca moraine, and are enclosed by confusedly grouped hilly deposits partly of till and partly of modified drift.

Neither this chain of lakes, nor that beginning with Sylvan and Gull lakes, can be ascribed to stream erosion while the ice-sheet was retreating or during the subsequent time. So far as they are enclosed by stratified drift deposits, they must have been due to remnants of the departing ice filling these hollows; but it seems difficult to account for the successive existence of such ice masses along these definite south to north and northeast courses. No till is spread over the adjoining modified drift, and these lake chains therefore cannot be explained, as in Martin county,* by the partial filling of interglacial stream courses with the drift of a later ice advance. They do not here mark avenues of drainage, unless they may in some degree represent preglacial valleys not wholly obliterated and filled by the mantle of the drift. Instead, they evidently owe their contour chiefly to having been the sites of the latest remnants of the ice-border while it was being rapidly withdrawn, with accompanying rapid sedimentation on each side.

Ice-formed ridges on lake shores. Ridges of sand and gravel four to six feet above the ordinary level of the lakes (which is commonly one to two feet below the highest stages), and having a width of about 100 feet, are sometimes seen dividing one lake from another. In numerous cases, a smaller and usually very shallow lake

* Geology of Minnesota, vol. i, 1884, pp. 479-485.

or a marsh has been thus separated from a larger lake basin. Such ridges on lakes enclosed by modified drift are seldom more than a quarter or third of a mile long, and they are mostly attributable quite as much to winds and wave-building as to ice-pushing.

On shallow lakes having shores of till, ridges of similar size are perhaps equally frequent, being there made up largely of boulders. These low ridges have been formed principally by the expansion of the ice during each winter, pushing the boulders and other drift outward from the shallow lake bed to the shore.

Alluvium. Since the close of the Glacial period, much stream channelling has taken place, and the resulting deposits of fine silt on the bottom lands of the rivers are alluvium, of scanty area and thickness in this district, to be distinguished, as different in origin and methods of transportation and deposition, from the stratified beds of the streams that flowed from the departing ice-sheet. The formation of the alluvium has been very slow in comparison with that of the modified drift.

MATERIAL RESOURCES.

The timber of this district, the fertility of its soil for agriculture, and the water-power of its streams, are its chief resources. It is well fitted, also, by its multitudes of lakes and streams and its extensive wooded areas, to be the resort of sportsmen and of the many who in their summer vacations seek rest in the country from the toil and care of the diverse and exacting occupations of the city. Deer, hares, partridges (grouse), ducks, trout, bass, and whitefish, here reward the skillful gunner and angler.

Among all the species of fish in these lakes, the whitefish is probably the most valuable. It is abundant in deep cool lakes, which receive inflows of springs. The whitefish grows to a maximum weight of about ten pounds in Whitefish lake and many others, including a second and smaller lake of this name (translated from its Ojibway designation) on the Boy river in the south part of T. 140 30, and the higher Fourteen Mile and Ten Mile lakes of the same stream.

Forestry. The cutting of pine timber (here about half white pine and half Norway or red pine) and its transportation to the Mississippi river for manufacturing into lumber, chiefly by the saw-mills of Brainerd, Little Falls, St. Cloud, and (in largest amount) Minneapolis, have constituted the principal industries of this district to the present time. The supplies of merchantable pine, however, are approaching exhaustion, and agriculture must be the principal resource of wealth in the future. During the winter of 1892-93, according to the estimates in the surveyor general's office, the amount of pine timber cut and to be floated down on the Bear and Leech Lake rivers was 14,978,120 feet; on the Vermilion river, 11,991,350 feet; on the Pine river, 122,536,700 feet; on the Little Pine river, 8,122,420 feet; and on the Crow Wing river, 49,148,350 feet. Besides these, the district supplied much timber to the headwaters of the Willow river, before noted in the chapter on Aitkin county, and directly to the Mississippi, on which, according to the same records, the cut of pine logs was 125,000,000 feet. These additions probably offset the portions received on the Crow Wing river from areas west and south of this district, so that its total supply of timber in this single winter was approximately 206,000,000 feet, being nearly one-third of the entire product (677,836,540 feet) upon the upper Mississippi and all its tributaries above Minneapolis.*

The Northern mill company, successor to the Gull River lumber company, cut during this winter about 75,000,000 feet of pine timber, of which some 10,000,000 feet were driven down the course by the Gull lakes and river and onward by the Mississippi to Minneapolis. The remaining 65,000,000 of this company's timber were transported by railroad to their mill at Brainerd, partly to be sawn there and partly to be put in the Mississippi river and thence floated to the company's Minneapolis saw-mills. For bringing the logs to the

* *Mississippi Valley Lumberman* (Minneapolis), June 30, 1893.

Brainerd mill, this company in 1892 constructed the Brainerd & Northern Minnesota railway, about forty miles long, to Munroe and Spider lake, with two branches respectively four and six miles long, extending westward and northeastward from Munroe. January 1st, 1893, the log-carrying by this railroad began, and in the next seven months the 65,000,000 feet of timber were brought to Brainerd. Two trains, of about twenty cars in each, made two trips daily in this work. During the winter this company employed several hundred men in cutting logs; about eighty men were employed in loading the logs on trains; and about 300 men in the steam saw-mill, planing-mill, and lumber yards, at Brainerd. These mills can produce 200,000 feet of sawn and planed lumber in a day's work of ten hours. During 1894 the railway west of lake Hubert was taken up; and a new line, about fifty miles long, was constructed by the same company, from lake Hubert north to the South arm of the West bay of Leech lake.

Another railroad for lumbering purposes, built for the Cross Lake logging company and known as the Mississippi & Northern railroad, extends twenty-three miles from Cross lake north to the Boy river. This railroad, like the preceding, has several supply branches, one of which runs from it west to Little Norway lake. Logs from the upper waters of Boy river are floated down to Girl lake, from which they are loaded on trains and carried to Cross lake, whence they are floated down the Pine and Mississippi rivers to the Minneapolis saw-mills.

Agriculture. Already a considerable number of farms, both on the tracts of modified drift and of till, have been cleared and under cultivation ten to twenty years. Some of these farms are at the lumber camps of the pineries, five to ten acres being cultivated by each proprietor or company doing a large business for the supply of provisions during the winters when many men are employed in cutting and hauling logs. The principal crops are wheat, barley, oats, corn, hay, potatoes, turnips, and other garden vegetables and small fruits, as strawberries, gooseberries, currants, and raspberries.

Dairying and stock-raising are doubtless destined to become prominent branches of the farm industries of this region, although the winters are long, requiring cattle, horses, and sheep to be fed in the barn during about half the year. At present the natural meadows along the streams supply the greater part of the hay for wintering stock, including the large numbers of draft horses and oxen used for the operations of lumbering. This native hay often consists principally of the blue-joint grass (Deyeuxia or Calamagrostis canadensis), growing four to six feet high and yielding two tons per acre. On uplands the cultivated herd's-grass or timothy, red-top, and other species, yield well; and with the native blue-grass (Poa pratensis) and red and white clover, they make a durable pasture sward.

Water-power. For the purpose of supplying an increased flow of the Mississippi river during the late summer and any other times of drought, in the interests of steamboat navigation below Saint Paul and subordinately of the flouring mills and saw-mills using the water-power of this river at Little Falls, Sauk Rapids, Saint Cloud, and Minneapolis, three large dams, namely the Winnibigoshish, Leech lake, and Pine river dams, have been constructed in this district by the United States government. These are portions of a reservoir system on the headwaters of the Mississippi, which also includes the Pokegama dam in Itasca county and the Sandy lake dam in Aitkin county.

The Winnibigoshish dam, on the Mississippi river at the mouth of lake Winnibigoshish, when at its usual stage of flowage, raises this lake eight feet above its former low water level, the area so flowed being about

seventy-five square miles. At its maximum capacity, however, this dam may raise the water of lake Winnibigoshish six feet higher, to a total head of fourteen feet, at which stage it would also raise Cass lake, with its Pike bay four feet above their stage of low water. The added area of flowage then would be about forty square miles, making the total maximum area of this reservoir about 115 square miles.

Leech lake, covering about 165 square miles, is usually raised by the dam on its outlet, nearly one mile from its mouth, to a hight of three or four feet above its former lowest stage; but this head may be increased to six and a half feet.

On the Pine river, the government dam, built at the mouth of Cross lake, usually holds this lake about nine feet, and Pine, Daggett, Rush, Whitefish, Trout, and Hay lakes from eight to two feet, above their former hights. Its maximum capacity of flowage, however, provided for in building the dam but not expected to be used, would raise all these lakes ten feet higher.

Above this dam, the Pine river and its branches have several dams, built by the lumbermen to supply water in the log-driving season, by which Norway lake, lakes Ada and Hattie; Pine Mountain lake, and others, are made reservoirs, their average head being probably about five feet.

The Boy river, likewise, has several low dams for log-driving. Others are on the Bear and Vermilion rivers. The principal dam of the latter stream, flowing the Big Vermilion lake, is reported to have a head of six feet; below which a small dam of two feet is at the mouth of the Little Vermilion lake.

On the Willow river and its North and South forks, above the Shovel lake dam, which is in Aitkin county, this district has the following six dams for logging, as reported in ascending order by Mr. Martin M. Watson, of Aitkin: the Rice lake dam, in the S. W. ¼ of sec. 19, T. 141-25, having a head of six feet; the Poplar Knoll dam, in the north edge of the S. W. ¼ of sec. 6, T. 141-25, with seven feet head; the Layton dam, in the northeast corner of sec. 31, T. 142-25, six feet; the Box dam, near the middle of the north half of sec. 28 in the same T. 142-25, just below the junction of the two forks, with head of nine feet; the North Fork dam, near the centre of sec. 1, this township, four and a half feet, flowing North Fork lake; and, on the South fork, the Watson dam, in the east edge of sec. 35 of the same township, having six feet head.

At the mouth of Gull lake, a dam raises this and Upper Gull lake and lake Kilpatrick about four feet. Two other dams, each of four or five feet head, are reported on the Gull river between the Upper Gull lake and lake Mayo, the upper one flowing lakes Mayo and Sibley. On the Cullen brook, tributary from the northeast to the Fish Trap brook and Upper Gull lake, a dam of only three feet head flows the three Cullen lakes. Home brook, tributary from the southwest to lake Kilpatrick, is reported to have three dams for lumbering: the first, about three miles, by the course of the brook, above its mouth, has six feet head; the next, two and a half miles farther, about four feet; and the highest, again two and a half miles above the foregoing, five feet.

All these dams are constructed for reservoir uses, and their valuable water-power is at present unemployed. It seems probable, however, that some of these sites will be occupied, in the not far distant future, by flouring mills, and, with the full development of manufacturing industries in the Northwest, perhaps also by woolen and cotton factories like those of the Merrimac, Androscoggin, Mohawk, Genesee, and other New England and New York rivers. The many lakes on the streams of this district, dammed to become reservoirs, will provide water-power of permanent and nearly uniform amount throughout the year, which is the most necessary condition of its successful use for manufacturing.

Springs and wells. From the porous modified drift there issue many springs along the ravines and valleys of the principal streams and upon the banks of lakes. They show that the plane of saturation lies at no great depth beneath all the flat or moderately undulating tracts of sand and gravel, where wells, penetrating to that plane, find a plentiful supply of water usually within fifteen to twenty-five feet below the surface. On till areas, though wells likewise generally obtain ample water supplies at similar moderate depths, they occasionally are obliged to go much deeper before reaching any water-bearing layer. The water, both of springs and wells, is of excellent quality, though "hard" for use with soap because of its dis-

solved lime and magnesic carbonates. Only one artesian well, situated in Brainerd and described on page 75, is obtained in this part of the state.

Numerous large and cool springs, issuing on the northwest shore of the Mississippi, near its low water line within a quarter of a mile below the bridge and dam a half mile distant to the southeast from the southwestern arm of lake Gilbert, probably come from this lake, flowing through the intervening ridge of very porous kame drift.

Chalybeate springs are frequent, though not more so, probably, than in most other parts of central and northern Minnesota. One of remarkable size and abundant iron-rust deposits is reported by Mr. William E. Seelye as flowing into the south end of the southwestern arm of Leech lake. At another locality, on the southern part of the Itasca moraine belt south of this lake, he found much bog iron ore deposited along a very springy small watercourse for an extent of at least a hundred rods.

CHAPTER IV.

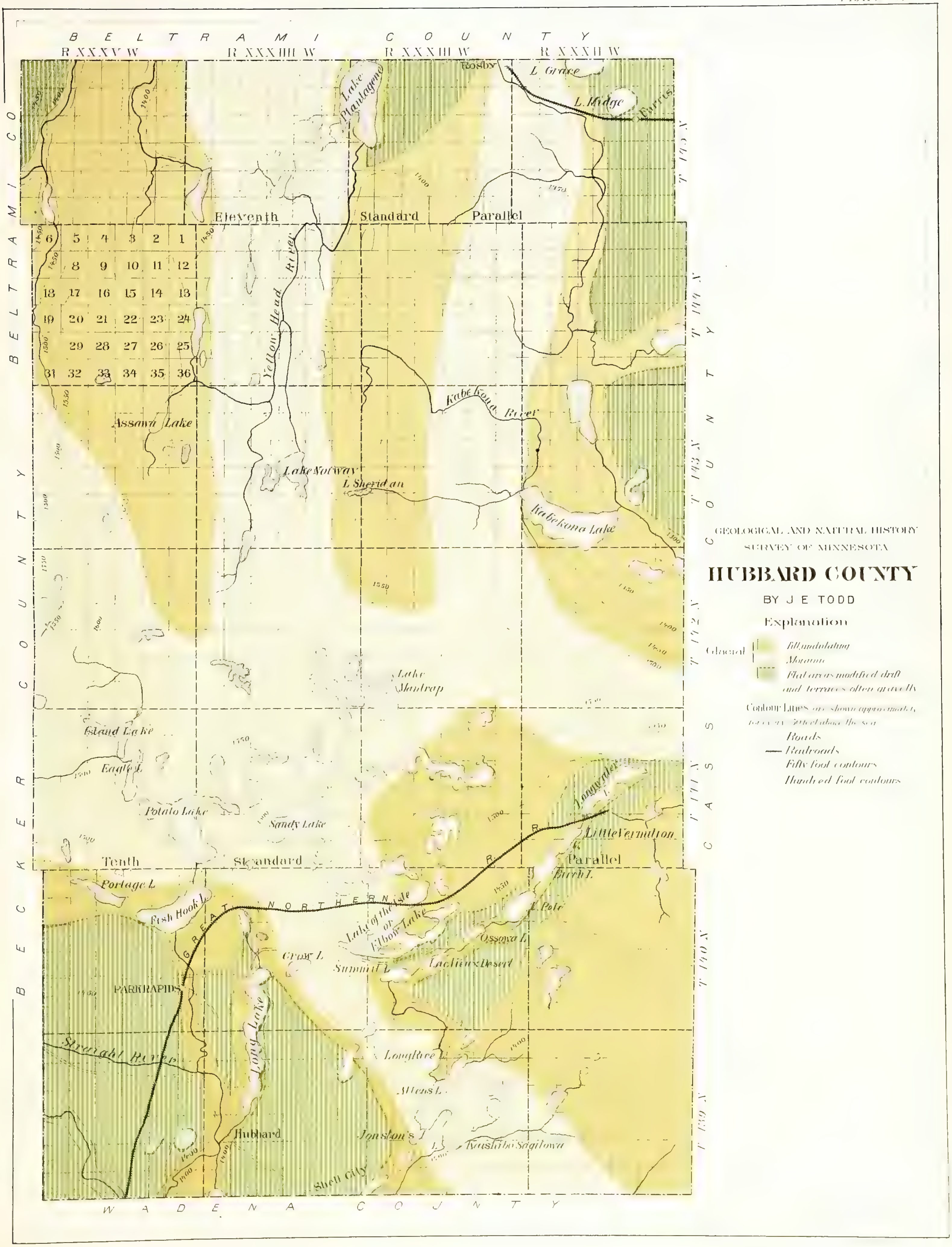
THE GEOLOGY OF HUBBARD COUNTY AND NORTHWESTERN PORTION OF CASS COUNTY.

BY J. E. TODD.

Location and area. This county (plate 59) is located in the north central portion of the state. It is bounded on the south by Wadena county, on the west by Becker, and on the east and north by Cass. Its area includes sixteen government townships, 585.40 square miles, or 374,657.12 acres. It is estimated that 62.57 square miles or 40,045.25 acres are water. This is in the form of numerous lakes, none of which are of wide extent; some attain a length of five or six miles. It lies in close proximity to the head of the Mississippi river, lake Itasca almost touching its western border. It includes some of the higher lands of the central portion of the state.

Its settlements are few, and confined to the southern portion of the county. Park Rapids, a thriving town of about 500 inhabitants, is the county seat, located in the east edge of Fish Hook prairie on Fish Hook river, and the present terminus of a branch of the Great Northern railway. An older settlement, Mantersburg, now called Hubbard, is located at the south end of Manter's lake. The principal industry of the county is lumbering, the Crow Wing river being its principal natural outlet.

The first explorer who crossed the county was Schoolcraft, who was sent by the general government to explore the sources of the Mississippi river. He ascended the Schoolcraft river and passed through the extreme northwestern corner of the county to lake Itasca. J. N. Nicollet, another government explorer, in 1836, passed through the extreme northern limit of the county in going from Leech lake to lake Itasca. Mr. O. E. Garrison, a surveyor of twenty years' acquaintance with the upper Mississippi region, was commissioned by the state geological survey to explore the sources of the Mississippi in 1880. He ascended the Crow Wing and Fish Hook rivers and took careful note of the topographic features, vegetation and location of the streams. In 1887, Mr. Warren Upham, of the state geological survey, touched the western border of the county in a trip to lake Itasca. An interesting account of his trip is given in the bulletin of the Minnesota Academy of Natural Sciences, vol.


BELTRAMI COUNTY
R XXXV W
R XXXIIII W
R XXXIII W
R XXXII W
BELTRAMI CO
BECKER COUNTY
CASS COUNTY
WADENA COUNTY
T 145 N
T 144 N
T 143 N
T 142 N
T 141 N
T 140 N
T 139 N
Lake Plantagenet
L Grace
L Midge
Farris
Eleventh Standard Parallel
Yellow Head River
Assawa Lake
Lake Norway
L Sheridan
Kabekona River
Kabekona Lake
Lake Mantrap
Island Lake
Eagle L
Potato Lake
Sandy Lake
Tenth Standard Parallel
Portage L
Fish Hook L
Great Northern R R
Longwater L
Little Vermilion
Birch L
L Pole
Lake of the Isle or Elbow Lake
Ossowa L
Crow L
Summit L
La Cl... Desert
PARKRAPIDS
Straight River
Long Lake
Long Rice L
Allens L
Hubbard
Jonston's L
Shell City
Kaslabo Sagitowa
GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA
HUBBARD COUNTY
BY J E TODD
Explanation
Glacial
Moraine
Flat areas modified drift
and terraces often gravelly
Contour Lines
Roads
Railroads
Fifty foot contours
Hundred foot contours

iii, No. 2. The report of Garrison's exploration is given in the ninth annual report of this survey. The writer has only had the opportunity of examining the county along the Great Northern railroad and the trails from Leech lake to White Earth and from Park Rapids to lake Itasca. Considerable additional information has been gathered from residents and lumbermen.

SURFACE FEATURES.

Topography. The general slope of the southwestern half of the county is toward the south; in the northern extremity toward the north, while small portions on the eastern border are inclined eastward toward Leech lake. Its general altitude varies from 1,400 feet above the sea on the south to 1,600 feet or more on the northwest. Its surface, except in the southwestern portion, is more broken than most of the state. It exhibits features common to the counties along the divide between the Mississippi and the Red river. West of Fish Hook river the surface is a sandy plain. North of a line entering the county near the southwest corner of T. 142-35, running southeast, passing north of Fish Hook lake and thence eastward toward Leech lake, the surface shows the usual features of a prominent moraine, the high stony knobs rising from 50 to 150 above the interspersed lakes and marshy basins. The width of this morainic strip has not been definitely determined and as has been suggested further on may not be strictly continuous. About the headwaters of the streams draining to the north the surface is less broken and lies in high sandy ridges trending north and south with valleys of erosion between them. The lakes for the most part are without outlets and usually have abrupt sides, are uniformly deep and are filled with pure water. Some of them present fine stretches of sandy beach, but usually their shores are marshy or walled with steep slopes of bare boulders. In the southeastern part of the county the surface resembles that in the extreme north, the valleys trending toward the southwest. A branch from the central morainic area extends from near Fish Hook lake in a southeast direction, probably to the northeast corner of Wadena county. Its hills are not so high as those already mentioned.

Lakes. While their general features have already been stated, we will briefly enumerate in detail some of the more important lakes.

Little Man Trap lake, two miles in length. on the west side of T. 142-35, is the head of the principal branch of Crow Wing river. It derives its name from its very irregular form. Its relation to the steep hills makes it difficult to pass for one traversing the forest. Potato lake, lying mostly in the southeast corner of T. 141-35, is about five miles in length along its curve, its southern end is about a mile in width, its main portion extends northwest nearly three miles; on its northeastern side extends a curved channel resembling a hook. About two miles south of Potato lake is Fish

Hook lake. Both of these lakes are traversed by the channel of Fish Hook river, the longest branch of Crow Wing river. Manter's lake is a long narrow lake extending about six miles north and south in Ts. 139, 140–34. It lies in a deep valley and connects at its south end with Shell river. Man Trap lake is a very irregular lake surrounding the southeast corner of T. 142-34. It is about five miles in length east and west and probably has thirty or forty miles of shore. Another very irregular lake called Crooked lake, lies in the north half of T. 141–33. Its sinuous form is fully six miles in length but nowhere more than one-half mile in width. Sand lake lies about three miles east of Potato lake. It is named from the extent of sandy beach along its western border. It is surrounded by high hills and is seventy feet deep. Elbow lake is about six miles east of Park Rapids and has a length of six miles in the same direction. Near its western end on the north side there springs a branch running two or three miles in a northwesterly direction. The grade of the Great Northern railway lies along its north side, while the old trail from Leech lake to White Earth Agency runs along its south side. Saylor's lake is a large one of a cluster of lakes in T. 139–33.

A very remarkable chain of lakes extends from about three miles east of Manter's lake in a quite direct line northeast to the west side of the southwestern point of Leech lake. The whole number of lakes of considerable size is about a dozen. They are sometimes named by numbers, a few have special names given them. The largest one which lies a little beyond the limits of Hubbard county is marked on some maps as Kaginogamaug or Long lake, also Crow Wing lake, and the one next to Leech lake is called War Pool lake. These lakes lie in a river-like valley with abrupt sides from twenty to forty feet in hight. They are elongated in the direction of the valley. They are usually connected by a distinct watercourse. They form the headwaters of Crow Wing river and are utilized for driving logs into that stream. Long lake, the Eleventh lake, is 1,390 and Fifth lake is 1,378 feet above the sea, the others grading regularly between.

On the northern slope of the county there are three or four prominent lakes connected with the east branch of the Mississippi, known also as the Naiwa, Yellow Head, or Schoolcraft river. In T. 143-34 are three lakes from one to two miles in length. The eastern one, lake Sheridan, lies at the head of the valley draining into lake Kabekona. The one next west is called lake George or Norway; the third, lake Paine. The last two empty into Lizard river, a branch of the Schoolcraft. In the northeastern corner is lake Assawa, named by Schoolcraft lake Alice. It was from this lake that both Schoolcraft and Nicollet made portages to lake Itasca.

Drainage. The principal stream draining the county is Crow Wing river, which rises in the remarkable chain of lakes before mentioned. It leaves the lakes near the southwest corner of T. 140–33, and after passing through Saylor's lake, and others associated with it in the township south, it receives the waters of Shell river just before it leaves the county. Shell river rises in Shell lake in Becker county and crosses the extreme southwest corner of Hubbard at a point where it approaches the southwest corner of T. 139-34. It receives the headwaters of Fish Hook river, which stream is the longest one in the county. The latter rises in Little Man Trap lake and after a very irregular course in Becker county it returns southeast to Hook, Potato or Arago lake, thence runs southward in a quite direct course, leaving the county near the northwest corner of T. 139–34, as before stated. Fish Hook river receives another important branch from the west called Straight river. It rises in Straight lake in Becker county and flows through the northern portion of T. 139–35 and joins Fish Hook river above the outlet of Manter's lake. In the northernmost townships of the county there are three small streams flowing quite directly northward, which empty into the Mississippi by way of Schoolcraft river.

GEOLOGIC FEATURES.

There are no known exposures of bed rock in the county. The whole area is deeply covered with glacial drift. There have been no deep excavations made, for the abundance of water at or near the surface and no supposition of mineral wealth have removed all incentives to such explorations. The nearest exposure of bed rock is the slate and dioryte near Motley, in the northeast corner of Todd county,

thirty-six miles south. At a greater distance east bed rock has been found on Little Boy river. It seems not improbable that the lower Paleozoic formation may underlie the county and possibly the lower Cretaceous may be struck in patches.

The geological formations are naturally divided into glacial deposits and recent formations. The former are represented by the till both of the plains and moraines, and the modified drift, including the higher terraces. Alluvial and lacustrine deposits of limited extent constitute the recent formations.

Glacial deposits. These include all that were formed during the occupation of the region by the ice-sheet during the Glacial epoch and those formed during its retreat by its direct action and by the action of the waters attending it. Scratched boulders and pebbles of foreign origin are the most obvious characteristics of this formation. These pebbles and boulders are usually of the toughest rocks, mostly crystalline, which have survived the tremendous grinding action of the glaciers.

Till. This is the most abundant of the glacial deposits and forms the universal base and principal body of the glacial drift. It is an unstratified mixture of sand, clay, and boulders in different proportions in different localities. So far as has been observed in the county it has a uniformly ashy gray color sometimes stained with vegetable matter, and probably deep below the surface shows a darker hue, but not of the deep blue character which is usually found in the drift of the Minnesota valley. A few shallow cuts along the railroad were the only accessible exposures of this deposit.

Boulders. The extreme scarcity of limestone pebbles and boulders is perhaps the most notable characteristic of the drift of this region. This characteristic is shared by the upper portion of the Mississippi basin. Dr. J. R. Walker, for many years Indian agent at Leech lake, informed me that in his traveling through the region he had found but one limestone boulder, and that in Leech Lake river near Mud lake. In my first passage across the county along the Leech lake trail to Park Rapids and thence to Itasca, not a boulder nor pebble of limestone was found, though constant search was made for them, until several were found on the beach at the north end of lake Itasca. Mr. Upham reports finding no limestone in his trip to lake Itasca. But on the other hand, Mr. Garrison reports his observation upon the pebbles in Fish Hook lake as being twenty-five per cent. limestone. He also calls attention to the incrustation of the rocks in Fish Hook river. An examination of the freshly cut grade of the railroad east of Park Rapids disclosed three or four boulders of yellow limestone and numerous pebbles. They were of a soft, impure, yellowish dolomyte, not of the hard, tough variety seen along the Minnesota and James valleys. A possible explanation of this discrepancy of observations may be found in the dissolving of the limestone upon the surface by the action of decomposing vegetation, while in fresh exposures or where streams have been active in

excavating, it has not been exposed long enough to such influences to disappear.

The prevalent boulders of the region are a fine grained granite of whitish tint, though a pinkish tint is less common. Trap and eruptive rocks are not abundant, a fine green basalt is especially rare. A light green trap with white hard spots is more frequent; a light blue quartz porphyry was seen several times. A sandstone which is yellow on the outside and white on the inside is well marked and not very uncommon; sometimes banded pieces occur. It seems not improbable that the sandstone boulders may be remains of strata which contributed most of the abundant sand of the region to the drift. The black jasper or slate is not infrequently found. It sometimes shows a decomposition by weathering. Gneiss and hornblendic gneiss are common. A six-inch boulder of pegmatyte, and a hornblendic granite, showing feldspar grains four inches in length, were noted. Specimens of gneiss with many quartz veins and boulders of quartz as if from such veins, remind one of those observed on the shores of the Lake of the Woods and the Big Fork river.

Moraines. Mr. Warren Upham, in several places has expressed himself with reference to the moraines in this region, in a manner similar to the following quotation, taken from his account of a visit to lake Itasca, bulletin of the Minnesota Academy of Natural Sciences, vol. iii, No. 2:

> One of the most distinct morainic belts of this state, denominated Itasca moraine, extends with a width of five to ten miles from the south side of Pokegama and Leech lakes westward to Little Man Trap lake, to the southern arm of Itasca; thence following the hight of the land it bends northwest and north between Itasca and the source of the Red river and continues northward between the upper and lower Rice lakes to Clear Water lake, etc.

He further states that the southern border of the Itasca moraine, where it was crossed, is a stony ridge which is eight miles south of the extremity of the eastern arm of lake Itasca. There is little doubt that the region as outlined by him is most prominently morainic. The heavily wooded character and roughness of the region have rendered it impossible to study it as would be necessary to decide the several questions which rise concerning it. From a study of Cass county, north of Hubbard, as well as the southern portion of Hubbard county and the region south of Leech lake along the trails, the writer is constrained to present a different interpretation of the morainic features of the county, leaving to more favored students to determine which view may be correct. The southern limit of the moraine is reached near the middle of the east side of T. 142 36. It also extends southeastward along the north side of Fish Hook lake to a subdued bouldery belt with numerous small depressed basins about three miles east of Park Rapids. The number and arrangement of the lakes and streams indicate that it probably extends past Saylor's lake to the northeast corner of Wadena county. Between Park Rapids and Elbow lake its highest ridges attain an elevation of about fifty feet above Park Rapids. Mr. Joseph Sombs of Park Rapids, who has been acquainted with the region for years, informed me

that this broken country continued further southeast past the head of Pine river to the vicinity of Gull lake, in southern Cass county. The region in the southeastern part of the county, as traversed by the Leech lake trail, is moderately undulating but would not be considered morainic. Mr. Sombs also informed me that the most noted and highest divide of the morainic region passes from the west arm of Leech lake to a little north of Long lake and thence runs nearly northwest through towns 141–32; 142–33; and 143–34. He says that it touches the west end of lake Kabekona and passes three miles south of its eastern end. The direction and position of this second strip would correspond with the moraine found north of Cass lake, which is known to extend west and southwest across the Mississippi, several miles east of lake Bemidji. There is also a strip further north and curving west and south along the west side of Schoolcraft river. It also would correspond, eastward, to the morainic strip along the south side of Leech lake. The second mentioned moraine was examined by the writer north of Long lake in the northern part of T. 141–32 and found to be very rugged and grand in its development, with its high hills rising 100 to 150 feet above the lake south.

Stratified or modified drift. This constitutes much of the superficial portion of the glacial drift. It is usually distinguished from the till by its sandy character, and its being commonly found at lower levels. It has evidently been reärranged, if not at first deposited, by water. Garrison says: "The country along the north of the one (Shell river), and west of the other (the Fish Hook river) is radically different (from the region to the south of Shell river)."

The characteristic tree is still the black pine but there are also many small burr-oaks with aspen, birch, and iron wood with small prairies and openings. These openings have a character peculiar to themselves. As throughout the west the prairie oak openings were considered choice locations by the early emigrants, so here the black pine openings with the small prairies are the choice places.

This peculiar tract of country commences near the west bank of Crow Wing river where it runs south through Ts. 139, 140–33, and extends northwest to the range of hills dividing the head of Otter Tail or Red river from the Shell. The Shell river forming its southern boundary, it extends to a line of hills bearing N. 80° W., and crossing the 10th standard parallel to the north of Fish Hook lake.

This portion of the country is a quite level plain from fifteen to forty feet above the streams. The country in the southeastern townships is also quite sandy but more undulating and interspersed with basins and occasional patches of clay.

The sandy modified drift stands as a broad terrace along the chain of lakes at the head of Crow Wing river and about forty feet above the water. It is also similarly developed along Elbow lake and Fish Hook river. The railroad cuts show that its upper portions are beautifully stratified sand, loam, and gravel. Away from the streams upon the terrace-like plains, flat patches of clay occur as though deposited by water. This may be due to the reärrangement of the masses of till protruding through the sand.

The probable origin of the chain of lakes. Attention has already been called to the remarkable chain of lakes at the head of Crow Wing river. This feature

resembles the remarkable chains described by Mr. Upham in his geology of Martin county and similar cases are not infrequent in the vicinity of moraines. It appears evident that we have as a first condition for their formation a deep water-cut channel. Whether this be of preglacial character, as argued by Mr. Upham, or of subglacial origin, remains to be determined. The lakes are deep and seem part of a former connection between the west arm of Leech lake and the present valley of Crow Wing river. It is not difficult to imagine that, previous to the advance of the ice-sheet, a valley existed draining toward Leech lake. It may also be conceived that in some way the ice of the glacier should occupy this channel and so prevent its destruction. Such a supposition does not, however, explain how in the movement of the ice-sheet this channel should not have been so distorted and broken or filled as to be unrecognizable.

The other view conceives that the stream flowed underneath the ice somewhat as seen in the case of Muir glacier of Alaska and Humboldt glacier of Greenland. In case the movement of the ice should block or break the connection by which the water entered the channel, either from the upper surface of the ice or from underneath the ice, the channel might become filled with ice, either by the freezing of the water in extreme cold seasons or by the pressing of the ice into it from above. Should this take place shortly before the ice-sheet ceased its onward progress, in the stage of recession, the channel would be most deeply filled with ice and in the gradual melting away the englacial deposits would be arranged in a sandy plain before the ice should have entirely melted away. When at last the ice disappeared it would leave a cast of its form, or of the deeply projecting blocks, as deep lake-beds, more or less connected, such as we have already described. This view accounts for the repetition of these channels more or less parallel with one another and with all degrees of completeness, for it is conceivable that while waters escape in a general direction they may first escape through one channel and then through another. The older channels would be more distorted or broken into irregularly arranged lake beds by the subsequent movement of the ice, while the last one formed would probably keep its shape and position. Hence we look upon this chain of lakes as marking the former escape of water from underneath the deeper ice which rested upon Leech lake to the edge of the ice-sheet, when it rested along the line which we have traced as running from Fish Hook lake southeastward. A further discussion of this feature will be found in the next section.*

The probable glacial history of the county. Before leaving this interesting subject let us briefly sketch the probable history of the formations enumerated. According to Mr. Upham the movement of the ice sheet over this region was mainly

*There seems to be nothing in the phenomena of this old channel incompatible with the idea that it is an abandoned river-bed, due to the existence of a river that drained an ice-dammed lake, which covered Leech lake and the surrounding country before the ice had so far withdrawn as to allow of a discharge through the Leech Lake river to the Mississippi river.—N. H. W.

from the north and northeast. The county in the earlier portion of the Glacial epoch was deeply covered with perhaps two or three thousand feet of ice, at which time its edge was as far south as Minneapolis. After centuries of retreat the edge of the ice crossed the county from the vicinity of Little Man Trap lake to Fourteen Mile lake south of Leech lake, thus leaving the southern part of the county uncovered except by broad, shallow streams supplied from the melting of the ice.

This condition of affairs prevailed for a long time, during which the progress of the ice brought boulders and clay from the north and by its melting deposited them in the form of a vast ridge formed of a mixture of clay and sand, gravel and boulders, and a large mass of ice. When eventually the increase of warmth finally melted the ice more rapidly than it flowed southward, the edge of the ice retreated gradually from the county toward the north. The surface of this vast ridge accumulated, was at first probably not very uneven, but as the masses of buried ice gradually melted, there was left in their place lake basins, and smaller depressions, as we find them to-day. The waters escaping from the ice-sheet, and from these melting masses of ice, deposited the stratified drift which we have just described. The till is probably the mass of material accumulated underneath the ice-sheet during the time when it covered the whole country.

According to the other view of the arrangement of moraines, which we have presented, the movement of the ice upon this region was mainly from the east and northeast, possibly at times from south of east. As, according to the previous theory, the ice at one time deeply covered the whole state as far south as Minneapolis, it moved in what may be called two great streams, one coming down the Red river and Minnesota river valleys into central Iowa; the other came from lake Superior westward and deployed against the east side of the former stream. When at their maximum they were virtually confluent, but as they melted away they gradually became separated one from the other, and at a certain stage the Leaf hills were formed between them. These lie to the west of Itasca, forming the great divide between the Mississippi and the Red rivers. As the ice gradually dwindled away in periods of rapid melting alternating with periods when the edge was comparatively stationary, there came a time when the edge of the ice crossed the county from the vicinity of Little Man Trap lake to the northeast corner of Wadena county, leaving the southwestern portion of the county uncovered while the rest remained submerged. At this stage the Fish Hook river began its course, and the Crow Wing, after a considerable course underneath the ice, came forth in the northeast corner of T. 139-34. Manter's lake may have been a portion of an earlier drainage channel from the same quarter, through the line of Elbow lake, which may have branched underneath the ice, one branch coming from the north and the other from

the east. The ice lay along this line probably a comparatively short time, when it receded to a line extending northwest from the east end of Long lake in T. 141-32. It halted along that line until it accumulated the second mentioned, or Leech lake moraine, which occupies the northeastern portion of the county. At that time the upper portion of the Mississippi was probably uncovered as far east as lake Bemidji; the surplus waters escaping from the edge of the ice north, probably made their way over the divide into Clear Water lake or Sand river, into the Red river region, which was then occupied by lake Agassiz. It remains for the future students of this county to accumulate evidence which shall reveal the more minute and more interesting details of this remarkable history.

Recent deposits. These are so limited and so readily inferred from their relations to the streams and lakes that no attempt has been made to represent them on the map.

The lacustrine formations are represented by the accumulations of wash and vegetable material in the bottom of the numerous basins and lakes before mentioned. The different basins present the various stages in the process of filling; from those where the bottom is occupied by open water to those where a dry and grassy meadow fills the basin. The stages in the process may be sketched as follows: The first wash from the surrounding hills accumulates several feet of fine stratified material on the shores and bottoms of the lakes. Where there are considerable tributaries this process may go on quite rapidly and if the lake is shallow it soon becomes a marsh filled with various water-plants. This process of washing went on much more rapidly before the region was covered with forests. Next, the tamaracks and mosses begin to encroach upon the open water on the shore. The addition of silty material decreases and layers of vegetation accumulate several feet in thickness. Later the mosses become dry enough to support the grasses, which in time form the turf which destroys the moss. In the deeper portions of the basin at this stage it may have the character of a quagmire or quaking bog. Eventually the bottom of the basin everywhere becomes firm ground. In the large basins the action of the waves and ice interferes with the growth of vegetation and produces distinct beach deposits. Where the shore is gently sloping these are sandy and present the usual features of bars and spits. Where the sides are abrupt the rapid freezing of the lakes on the approach of winter tends to push the sandy beach into ridges by the expansive action of the ice. These, however, are apt to be washed down and rearranged as the lakes fill in early spring. The strong action of the ice upon the abrupt slopes where the boulders are more abundant pushes them into steeply sloping walls resembling the artificial riprapping of streams.

The recent alluvial deposits are almost entirely confined to the immediate

vicinity of streams. The streams cannot well be said to have bottoms or flood plains. Their banks are usually low and marshy and their fluctuations of level are inconsiderable, because of the influence of forests. The terraces, particularly along the streams at a hight of a few feet, are in most cases, if not in all, to be referred to the Glacial epoch and will be considered under the next head.

ECONOMIC FEATURES.

The results of the Glacial epoch have contributed to the resources of Hubbard county, not only in the beautifully varied topography which rivals that of the far famed lake region in the north of England but has made it the natural home for game of all kinds. As the country is developed and railroads make it easy of access, it will be an important portion of the numerous similiar summer resorts for the tourists and sportsmen. At present the woods abound in deer and grouse, while the lakes flutter with geese and ducks, and swarm with fish of the most attractive kinds. Leech lake and lake Itasca may become centres of recreation, while the smaller lakes near will form important portions of the sportsmen's ground.

Wells. As before stated, the whole country is abundantly supplied with wholesome water easily accessible. In the flat regions of stratified drift the water is abundant in wells at a few feet from the surface. The sections of some of these wells are reported as follows:

At Park Rapids several wells were noted by Mr. Garrison and he gives the following as typical:

12 feet sandy loam;
4 inches sandy clay;
1 foot gravel and sand interspersed with small rounded stones and coarser sand and water which was 3 feet deep.

At Howard on section 20, T. 139–34, he found a well thirty six feet deep, showing only three feet of sandy gravel and loam, twenty-eight feet of sand and gravel, followed by quicksand bearing water. Other wells in the vicinity reached the bouldery clay at from thirty-two to forty-two feet.

At Colgrove's, southeast quarter of section 12, T. 141–36, upon the terrace near Fish Hook river a well was driven forty feet; fifteen to twenty was pure sand and apparently below, hard clay with boulders. Water in the early occupation of the country is usually obtained by sinking shallow wells in the edge of a lake or swamp.

Vegetation. As already stated, the county is mostly covered with forests, but in the southwestern corner are small prairies of limited extent, the largest of which is Fish Hook prairie. These prairies occupy the surface of stratified drift, and are the outliers of the more continuous prairie found in the western portion of Becker county and west of the Leaf hills. Of the forest, the black pine is the characteristic tree upon the dryer surface, while the aspen prevails upon the moist portions outside of the swamps. These two trees are arranged in patches alternating with one another in a very irregular manner. Instead of this distribution being the result of the "tension" or struggling for location it seems commonly to be a consequence of difference in the subsoil. In an examination of the freshly cut grade of the railroad to Leech lake, this became very manifest. In looking along the grade, wherever water stood in pools after a recent rain, the aspen was the prevailing tree,

while in the sandy stretches where water had sunk into the ground, the jack pine was always present. Where these two elements were intermingled or one of them but thinly developed upon the surface, there was a mixture of the two trees and frequently interspersed with the red and white pines.

Mr. Upham from his trip near Itasca reports the following:

"Three species of pines occur plentifully about Itasca. The red pine, commonly but erroneously called Norway pine, constitutes perhaps three-fourths of the timber available for manufacturing lumber. This species occurs 75 to 100 feet in hight and one-half to two feet in diameter. In its most dense groves it is almost unmingled with other species of trees, and its reddish brown straight trunks rise from forty to sixty feet to the first limb and are so thickly studded with their canopy of boughs as almost to exclude the sunshine. These groves have little or no underbrush and seem prepared by nature for picnic grounds. (See figure 1, plate D.) The white pine attains a hight of 90 to 125 feet, and has a diameter of two, three to four feet. It is about a third as plentiful as the red pine and occurs on more clayey soil, either scattered, or in groves through whose tops every wind plays inimitable music. The jack pine (*Pinus banksiana* Lambert) occupies the sandy and gravelly land, very abundant on such tracts as in the Itascan district far eastward and northward. It has a small and tall straight trunk from sixty to eighty feet in hight and nine to eighteen inches in diameter at the base. (See figure 2, plate D.) This species is used for fuel; and the Indians split and prepare its long pliant roots named *watab* for sewing together strips of birch bark for their canoes. Among the other principal forest trees and shrubs are the red oak, poplar, and aspen very plentiful. The larger are the toothed poplar, balsam poplar, cotton wood, canoe birch, black, and burr oaks, white elm, white and black ash, red and sugar maple, moose wood, wild plum, bird or pan cherry, high bush cranberry, common and beak hazel, prickly ash, willow, and alder. In the swamps and frequently in the higher lands the tamarack, black spruce, and balsam fir occur in abundance, often festooned with moss.

Mr. Garrison reports from Fish Hook lake the additional species of sheep-berry, shad bush, cockspur thorn, iron wood, and black cherry. Characteristic views of the red and black pines are shown in figures 1 and 2, plate D, from localities closely adjoining this county.

Grass, suitable for hay, outside of the prairies, is confined entirely to the swampy portions near streams and in lake basins, the latter being often remotely distributed through the region.

Water-power. Mill sites may be found along the streams, principally on Fish Hook river. About a mile from Fish Hook lake is an abrupt fall descending about twenty feet in a distance of forty to fifty rods. Other rapids are found higher up the stream. The stream is utilized for water-power at Park Rapids.

NORTHWESTERN PORTION OF CASS COUNTY.

Location and area. This area, which for convenience in mapping and exploration, has been assigned me, is equivalent approximately to fourteen government townships. It is that portion of Cass county lying west of the line which divides the ranges 31 and 32. It is bounded on the north and west by Beltrami county, the Mississippi river forming the boundary; on the south by Hubbard county, around which it is arranged on the north and east sides with a small portion overlapping the west side. This portion is wholly represented on the map of Hubbard county with the exception of narrow areas next the Mississippi which will be found on the map of Beltrami county.

FIG. 1. NORWAY PINE GROVE AT HACKENSACK P. O., LOOKING SOUTHWEST. (p. 92.)

FIG. 2. VIEW SOUTHEAST BY SOUTH FROM DIVIDE, ABOUT FIVE MILES NORTH OF ITASCA LAKE, SHOWING BLACK PINE FOREST. (p. 92.)

The expeditions noted under Hubbard county also traversed this region. Schoolcraft in his expedition to lake Itasca passed up the Mississippi to lake Bemidji and thence up Schoolcraft river, and on his return down the Mississippi to that lake. Nicollet and Garrison also passed down the Mississippi. The writer traversed a portion of the county north of lake Itasca and ascended the Mississippi from Cass lake to the mouth of the Schoolcraft, and the latter stream to a high point on sec. 3, T. 144-34, where from a high treetop an extensive view was obtained of the valley southward, and down the southeastern valley toward lake Kabekona.

SURFACE FEATURES.

Topography. This area presents similar features to those already described in the northern portion of Hubbard county. It slopes in the western portion toward the north and in the eastern half toward the east and south. Its highest points are toward the southwest. It shows much less distinctly the usual topography of glaciated regions than the central portion of Hubbard county. Lakes are less numerous and are generally without the abrupt sides and irregular forms which characterize prominently morainic regions. On the other hand, its western half may be described as consisting of a gentle northward slope on the south furrowed by three or four broad valleys running in general due north, and a quite flat plain on the north, with a quite abrupt drop between. The impression left from the examination of the northward valleys of the southern portion is that they are primarily due to preglacial erosion of the region; that the glacial drift having been spread over it as a blanket, reveals quite distinctly the main features of the preglacial topography. The eastern half, while in general showing similar features, has its valleys running to the east toward the western portion of Leech lake and ending in lake Kabekona. In the vicinity of the Mississippi along its easterly course there are quite extensive bottom lands; and east of the lower portion of Schoolcraft river the country is, much of it, level and low. While this may be given as a general description of the whole surface there are two strips of rougher land which may be traced as follows: One enters the county a few miles west of the mouth of Schoolcraft river and extends with a breadth of from four to five miles southward, west of lake Rahbahkona or Plantagenet and continues in the same direction into T. 143-34 of Hubbard county. The hills of this system rise from 50 to 100 feet above the adjacent streams. Another strip crosses the Mississippi river in the central portion of T. 146-32 and forms the lower portion of Metowsa rapids, as marked on Garrison's map. This turns shortly southward, and passing through range 33, touches the west end of lake Kabekona and connects with the hills already mentioned north of Long lake of the Crow Wing series. Mr. Upham in his bulletin on altitudes (U. S. G. S. No. 72) says, from

near Schoolcraft river to Leech lake, there is a morainic contour along the proposed extension of the Fosston branch of the Great Northern railroad.

ALTITUDES DETERMINED FROM RAILROAD LEVELS IN HUBBARD COUNTY AND NORTHWEST PORTION OF CASS COUNTY.

On the Park Rapids Branch of the Great Northern Railway.

Starting with Wadena which, according to the U. S. Geol. Survey Bulletin No. 72, is 1,350 feet above the sea, we find in comparing it with the report furnished by Mr. Upham that he gives it 1,346, while the chief engineer of the Great Northern railway has recently given it as 1,337. We take Mr. Upham's figures to be an average, which he has probably fully considered.

	Feet above the sea.
Wadena,	1,346
Leaf River station,	1,323
Sebeka,	1,388
Menahga,	1,405
Shallow River station,	1,419
Shallow river at Bridge, 1 mile south of station,	1,380
Park Rapids,	1,436
Straight river at the bridge, 3 miles south of Park Rapids, 1,403; Fish Hook river at the bridge ¼ mile north of Park Rapids, mill pond,	1,425
Elbow lake, crossed at its narrowest, 9½ miles from Park Rapids,	1,426
Crow Wing river, 8 miles from Elbow lake,	1,389
Akeley,	1,425
Leech lake,	1,295
Other elevations furnished by Mr. Upham, probably derived from this survey, are:	
Crow Wing or Eleventh lake,	1,390
Tenth lake,	1,387
Ninth lake,	1,386
Prairie or Eighth lake,	1,385
Seventh lake,	1,382
Sixth lake,	1,379
Fifth lake,	1,378

Extension of Fosston Branch Great Northern Railway.

	Miles from Carman.	Feet above the sea.
Fosston,	44	1,288
Mississippi river, sec. 8, T. 145-35, water, 1,373; bottom land, 20 to 50 rods, hight, 1,375; proposed grade of bridge,	77.1	1,409
Crow bed, hills rising east and west to 1,450-1460,	87.5	1,381
Schoolcraft river, on or near section 3, T. 144-34,	89.9	1,372
Summit, highest on this line of survey,	98.5	1,576
Leech lake, water raised by dam,	121.2	1,297

Mr. Upham, in bulletin 72, remarks: roughly morainic contour with elevations 25 to 100 feet above the hollows, extends to Leech lake, a distance of 30 miles.

Drainage and streams. The Mississippi river may perhaps be most appropriately described in connection with this area. Its source lies in Beltrami county and the questions of dispute concerning it will conveniently be postponed until that county is considered. Lake Itasca, which forms a portion of the boundary of Cass county, is an irregularly V-shaped lake with one arm extending south quite directly from its point to the north end about eight and a half miles in length. Its eastern arm extends southeast in a crooked manner about four miles measured along its crooks from its northern end. The lake is bounded with high drift hills, rising from 150 to 200 feet above the lake. The shore along the west side of its southern arm is quite generally marshy and slopes gradually. The southeast arm is bounded by hills from 75 to 100 feet in hight rising abruptly from the water. The greatest depth, eighty feet, is found in the southeastern arm. A small island in the lake near the junction of the arms is named Schoolcraft island. The Mississippi river leaves the extreme north end of the lake on the west side and turns at first abruptly westward. The current is sluggish and the stream is from twelve to twenty feet in width, eighteen to twenty inches in depth, with soft muddy bottom and shore. (See figure 1, plate E.) Shortly after the stream becomes too shallow to float a canoe. About two miles from the lake the river enters a tamarack swamp where its deep and very sluggish channel is nearly closed up by large growth of wild rice. This swamp continues for about three miles, but the river meandering through it is more than twice that length. A short distance below the swamp, Mr. Garrison, whose description we are mainly following, found a jam of drift-wood which proved to be the head of falls or rapids, over compact ledges of boulders. The fall was found to be about twelve feet in as many rods. "This was but the first of a series of rapids continuing for about a half a mile, when the river enters another swamp of tamarack and spruce but without the usual meadow on the bank."

FIG. 1. THE MISSISSIPPI RIVER LEAVING ITASCA LAKE, LOOKING EAST. (p. 94.)

FIG. 2. VIEW OF MORAINIC HILLS ALONG THE WEST SIDE OF LAKE MARQUETTE. (p. 97.)

Below this again were jams of drift-wood and rapids for about two miles more, descending probably from fifty to sixty feet. The river then reaches a level in which it flows as a winding channel in a broad grassy swamp which continues with more or less interruption by the narrowing of the valley in a northward and eastward direction to mouth of La Salle river; thence northward to sec. 58, T. 146-35, where it turns abruptly southward for two or three miles to the mouth of Hennepin river. It keeps, in general, an easterly course through similar wild rice marshes to the mouth of Schoolcraft river, which it joins at right angles and takes the course of the latter northward. Soon after it passes through lake Irving and next through a short strait into lake Bemidji. The full name of this lake is Bemidji Gamaug which is nearly equivalent to *Lac Travers* or Cross lake as Nicollet names it. This lake is about six miles in length and three miles in breadth, of quite regular outline, without islands, and from twelve to forty feet in depth. The Mississippi enters it with a considerable current and has formed around its entrance in the lake a semicircular bar of gravel upon which the water is from six to twenty-four inches in depth, and by which a wagon road, marked by stakes, crosses the lake. The river as it enters is about three rods in width and probably eight or ten feet in depth. The reason for the significant name, lake Bemidji (or lake that lies across) is that the river enters it at the south end and leaves it in easterly direction in the middle of the east side, so that in ascending the Mississippi the lake appears to lie with its longer axis transverse to the course of the river. Much of this lake has grown up to scattering patches of bullrushes, especially on the east and north sides. After leaving the lake, the Mississippi is very shallow, not more than six inches in depth, though having a breadth of perhaps fifty yards. The banks of the river are low, not more than from four to eight feet above the water, usually with gentle slope. About three miles east of the lake the river washes the base of an isolated hill fifty or sixty feet in hight, composed mostly of sand and clay. About six miles east of the lake the river turns quite sharply to the southeast. The bottom becomes more stony and is broken by rapids, necessitating portages; the low banks become higher, rising to a hight of thirty-five to forty feet above the water. This series of rapids, ten or twelve in number, is called the Metoswa rapids. After keeping a southeast course for about eight miles it enters a large lake, named Pamitascodiac, about two and a half miles in length, which it crosses at its northern end. It enters the lake by a very winding passage through a dense growth of cane lake grass, and the outlet is through a dense growth of bullrush. This lake was formerly connected by a portage to Midge lake. Leaving this lake the Mississippi passes eastward and enters and crosses the south end of a lake about five miles in length, called lake Andrusia. On a narrow land, separating lake Andrusia from the west end of Cass lake, is a mission and Indian village, which has long been the principal settlement of Cass lake.

La Salle river is a small stream about ten miles long, rising about three miles east of the north end of lake Itasca, flowing due north along the west side of towns in range 35. Hennepin river is of similar size and length, flowing through the eastern portion of the same townships and entering the Mississippi in sec. 35, T. 146-35, nearly opposite to the entrance of the Little Mississippi from the north side. These two streams scarcely deserve the name of rivers, being only small creeks. Schoolcraft or Yellow Head river, is about thirty miles in length, its longest branch rising a little northwest of Man Trap lake in Hubbard county. It receives, on the north boundary of that county, a branch from both the east and west and flows to the middle of the north line of T. 144-34, where it turns abruptly eastward through a range of hills rising from 75 to 100 feet above it, when it enters a broad valley which it follows northward to its junction with the Mississippi in sec. 28, T. 146-33. Its course above its entrance into the last broad valley is nearly due north, and much of the way in a wide valley with marshes and grass. In passing through the range of hills its course is winding with frequent rapids difficult for the passage of canoes.

Kabekona river rises in the northwest corner of T. 144-33, and flows in a crooked east-southeast valley into the west side of T. 143-32, when it turns abruptly south and three miles after enters the northwest end of lake Kabekona, from which it issues at the east end in a southeasterly direction, passing through the east end of lake Benedict and shortly after empties into Leech lake. The west branch of this river, as it may be called, enters the west end of lake Kabekona. Another branch, a larger one, lying north of lake Kabekona enters it soon after the main stream leaves lake Kabekona. Another river over twenty miles in length, whose name has not been determined, rises about four miles east of lake Marquette and flows southeast near Midge lake and thence a little west of south nearly to the middle of the south line of T. 144-32, when it turns abruptly eastward and after passing through Steamboat lake in that direction turns south into the northwest extremity of Leech lake. Another stream, Shingobe Minissibe, rises a little south of Long lake of the Crow Wing series in T. 141-32, flows into Diver lake in the same township, then keeps a northeast direction to the southwest extremity of Leech lake.

Lakes. The lakes of this region resemble in general those described in Hubbard county; being bounded by drift deposits and usually attended by marshes. They are generally, however, shallower and broader and with less abrupt sides than most of those in Hubbard county. None of them are arranged in series like those at the head of Crow Wing river. In the portion draining to the north all of the important lakes are connected with the streams. La Salle river passes through lake Beaulieau a mile and a half long and another of similar size near its mouth. The Hennepin river is not attended by lakes, except one two miles in length connected with its short east branch. Schoolcraft river is connected with eight or nine quite important lakes from one to four miles in length, all having their longer dimensions north and south. On the east side of T. 144-35 is lake Hattie, one and one-half miles in length, draining southward toward the outlet of lake Alice, into the west branch of the river. In T. 145-34 is lake Frontenac, connected with the middle of Schoolcraft river by a short outlet. The largest lake connected with this river is lake Rahbahkana, or Plantagenet, as named by Schoolcraft.

It is in an imperfectly double form consisting of a long strait lake three miles in length upon the east, with a deep bay connecting with it on the west side which is about three miles in length north and south. Its southwest shore is high and broken. Lake Marquette is a double lake consisting of two eliptical basins lying end to end. It lies about one-half mile north of the last mentioned lake. Another small lake is intercepted by the Schoolcraft just before it joins the Mississippi.

In the eastern half of this area, the upper lake is in the northwestern corner of T. 143-32, and has been named Garfield lake, though its Indian name Kabekona is commonly used. It is about four miles in length and one and one-half miles wide. Its southern shore is steep and hilly. It receives two streams at its northwest end, one from the west heading near lake Sheridan and the other from the northwest of Kabekona river. It is connected through the lower of Kabekona river with Leech lake. Another lake two miles and a half in length lies in the northern portion of the same township and is connected by an outlet with Kabekona river. Lake Benedict is about one and one-half miles in length extending east and west, scarcely separate from the west end of Leech lake, also connected with Kabekona river. Grace lake in the northern part of T. 145-32 is about a mile and a half in diameter. Midge lake about a mile and a half southeast of it is of importance because for some time it was the connection through a series of portages with a lake (Pamitascodiac) connected with the Mississippi, and the river south connected with the northwest arm of Leech lake. More recently this route has not been used, but instead the course more commonly taken is between the northwest arm of Leech lake and the south end of Cass lake through a chain of lakes which is east of our territory.

GEOLOGIC FEATURES.

Later deposits. This section, like Hubbard county, exhibits no exposures of bed rock; no excavations have been made to determine its depth below the surface. The deposits belong to the same classes mentioned under these heads in Hubbard county. The recent deposits are more extensively developed along the Mississippi and Schoolcraft rivers than anywhere in Hubbard county. This has already been alluded to in the description of these streams. Terraces of modified drift, mostly stratified sand with local developments of clay, are found along the Mississippi at a hight of from twenty to thirty feet. At some points lower terraces than the main one are found five to ten feet above the stream. These lower flats probably should be referred to the recent deposits.

Moraines. The morainic development of the drift is in some portions considerably scattered and feebly developed, but we shall conveniently group the various drift hills in three principal moraines:

The Itasca moraine. As we have already stated, the region about lake Itasca is very prominently morainic. The northern boundary of this feature may be approximately drawn as follows: It extends from a point about three or four miles north of lake Itasca northwestward, crossing the Mississippi near the middle of the north line of T. 144-36, and is understood to pass west of Upper Rice lake. It seems not impossible that the Itasca moraine in Hubbard county is an interlobate moraine with its apex pointing east.

The second moraine we may call the Schoolcraft river moraine. This is the one which we have already considered as passing east of Park Rapids and northward west of the head of Schoolcraft river. It leaves the county in the vicinity of lakes Alice and Hattie. Its eastern boundary passes along the west side of lakes Rahbahkona and Marquette, and thence northward along the west side of Ts. 146, 147-34. In the latter township it turns eastward and passes between lake Bemidji

FIG. 1. VIEW NORTH 65° WEST, SHOWING MORAINE TOPOGRAPHY TAKEN FROM THE POINT INDICATED IN FIG. 9 OF THE TEXT, p. 105. (p. 97.)

FIG. 2. LOOKING NORTH 30° EAST, FROM NEAR THE CENTRE OF SEC. 34, 150-40. (p. 105.)

and Turtle lake. The hills belonging to this moraine were noted by Garrison two to three miles west of the mouth of Schoolcraft river, and others referred to the same moraine are found along Grant creek in the north part of T. 146–34, thirty-five to forty feet above the surrounding country, and along the west side of lake Marquette, where they rise to a hight of seventy-five feet above the lake. The range rises still higher west of lake Plantagenet and from a high point of view on sec. 3, T. 144–34, these hills were seen to pass southward along the west side of Schoolcraft river, as before stated. Views of these hills are shown in figures 2, plate E, and 1, plate F.

The third moraine, which we will call Cass Lake moraine, enters the region at the west end of lake Kabekona and is believed to pass northward to the north line of T. 145–33, where it must pass northeast in order to cross, as it is known to do, the Mississippi river in T. 146–32, where it seems to form the Metoswa rapids, and thence extends northeast and east. On sec. 4, T. 146–32, the hills of this moraine rise from sixty to seventy feet above the Mississippi and are interspersed with typical kettle basins.

ECONOMIC FEATURES.

Vegetation. This resembles closely that of Hubbard county. North of lake Itasca, east of the Mississippi, much of the country is almost prairie, partly as a result of forest fires which have removed formerly abundant timber. Along the Mississippi are river bottoms sometimes sixty to seventy rods in width and often dry enough to be covered with luxuriant growths of blue joint and redtop grasses from which thousands of tons of hay might be prepared annually. The shallow lakes and the sluggish watercourses, as in the case of the Mississippi above lake Bemidji, abound in wild rice, which might be made to produce almost unlimited supplies of valuable food. It forms an important part of the sustenance of the Indians and grows luxuriantly without cultivation. These shallow marshes afford the food for numbers of migratory water-fowl.

The black pine is the prevalent tree of this region, which is generally sandy, and with it are associated considerable quantities of red pine, the tops of which rise majestically above the surrounding forest. Upon the lower lands and terraces, not only are found these two species, but in clayey localities the aspen, oak, elm, ash, etc. The principal part of Kabekona river is said to be through a rich country of hard wood.

This country is not occupied by settlers except a few sections north of lake Itasca. No data have been obtained concerning the wells, though from the sandy character of the soil and the abundance of moisture, no doubt they can be easily obtained at any point.

Water-power. Since the northward flowing streams and Kabekona river rise in the southwestern portion of a section which is elevated to a hight of 1,500 to 1,600 feet above the sea, while the elevation along the Mississippi is 1,375 to 1,350 and lake Kabekona 1,302, it is evident that the streams all have considerable descent and therefore valuable mill sites might be easily found. At no distant time it seems not unlikely that this region may be the location of numerous manufacturers particularly of wooden ware and lumber.

CHAPTER V.

THE GEOLOGY OF NORMAN AND POLK COUNTIES.

By J. E. TODD.

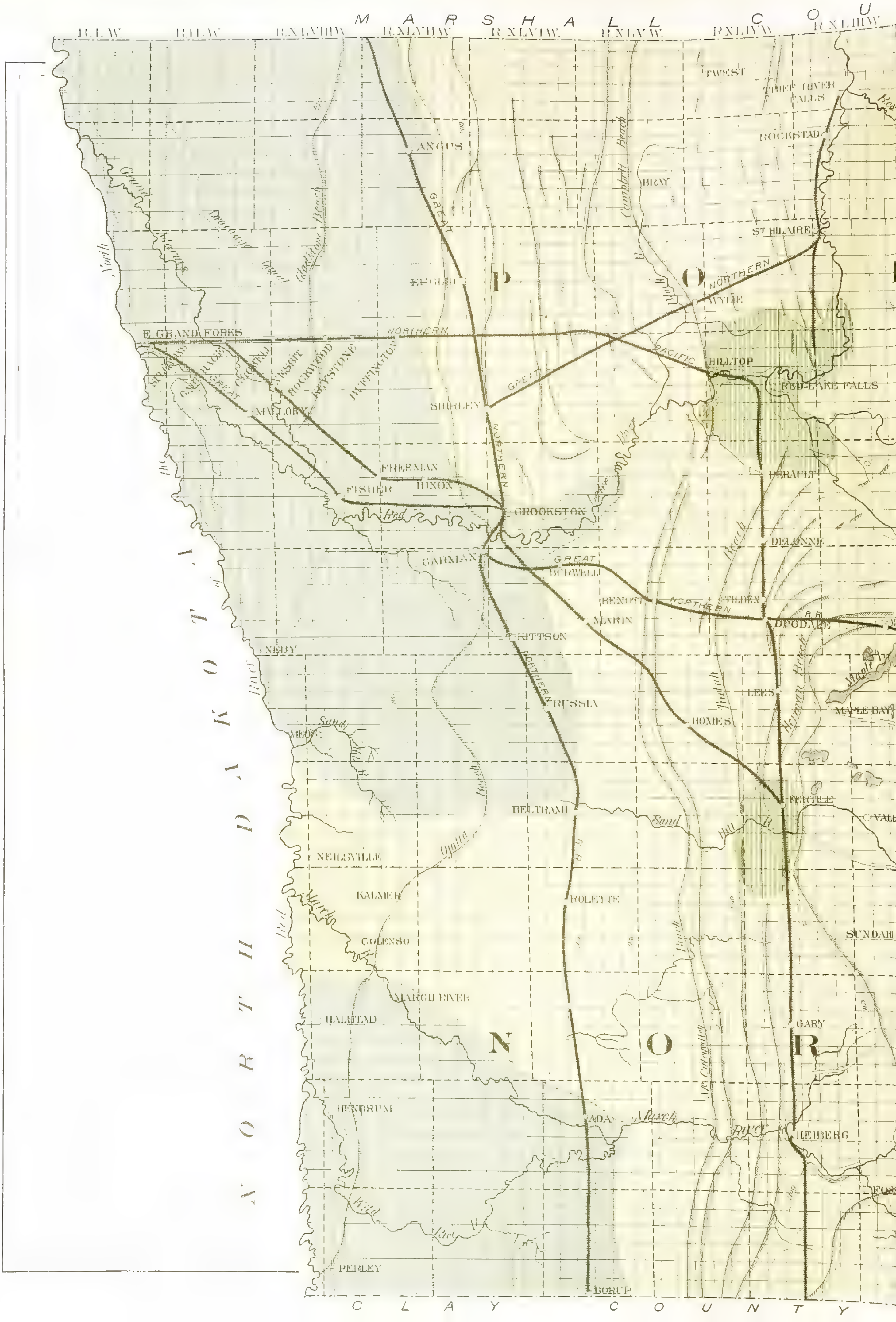
Situation and area. These counties (plate 62) are conveniently considered together, not only because of their form but also on account of their close similarity in topographic features and geologic structure. Norman county is bounded on the south by Clay and Becker counties; Polk county lies north of it. Both are bounded on the west by North Dakota with the Red river as boundary; on the east they are bounded by Beltrami county. The former is little more than ten townships in length and four in breadth; the latter county, owing to a turn in the Red river, is twelve townships in length at the north and eight townships wide from north to south. They are, therefore, both of them nearly rectangular, and one more than twice the size of the other.

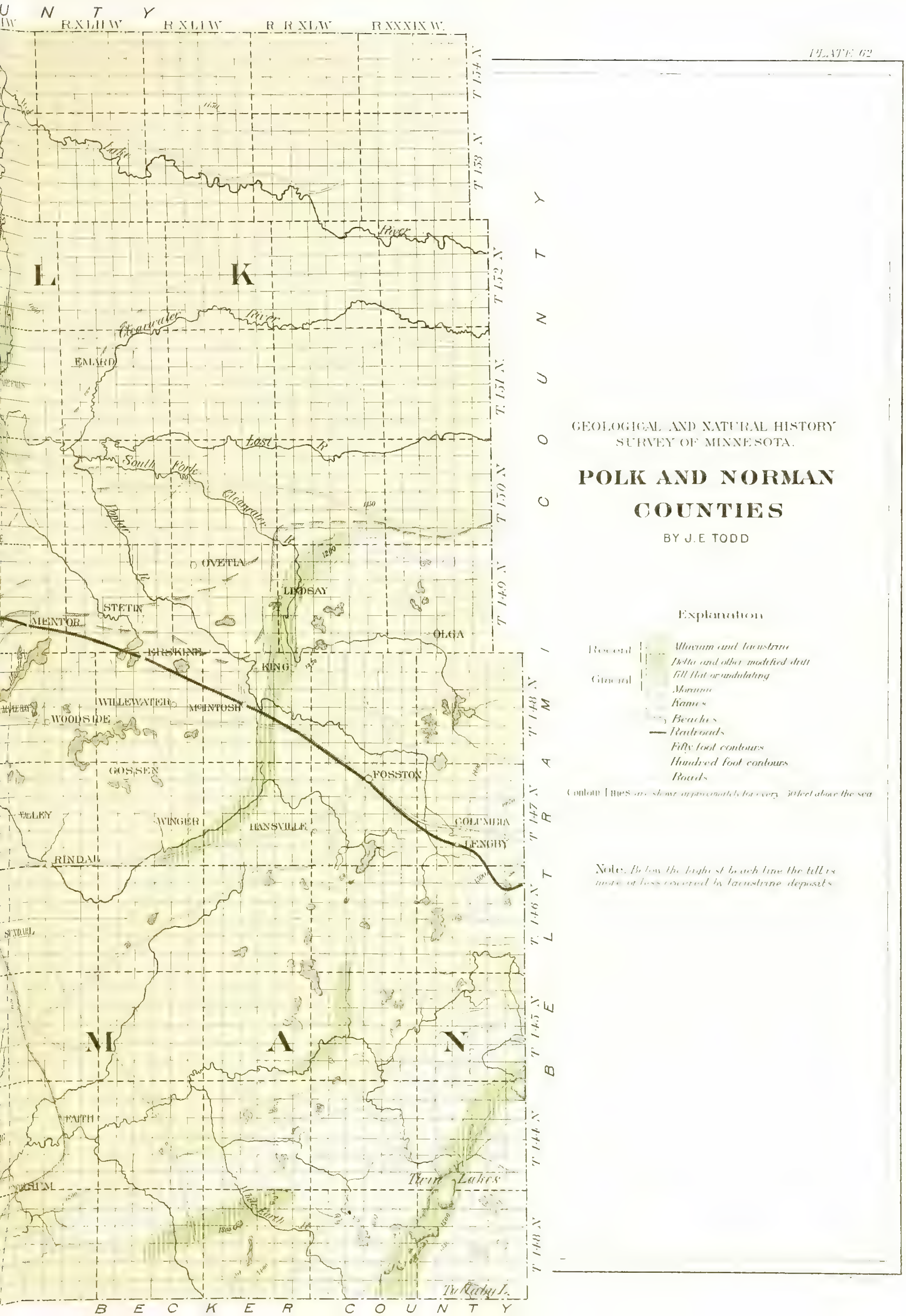
The area of Norman county is 1,458.32 square miles or 933,326.15 acres, of which 23.21 square miles or 14,853.55 acres are water. The county seat is Ada, on Wild Rice river. The eastern half is not yet occupied except by straggling Indian settlers, for the White Earth reservation includes the most eastern sixteen townships. Polk county contains 3,159.18 square miles or 2,021,873.25 acres, of which 41.91 square miles or 26,818.67 acres are water. The water of both of these counties is in the usual form of small lakes attending glacial moraines.

SURFACE FEATURES.

Norman county topography. Norman county reaches an elevation of 1,500 to 1,600 feet on its eastern border and declines to less than a thousand on its western. The slope is gentle to the edge of the table-land which lies approximately along the 96th meridian, when a descent of 300 feet occurs in about ten miles. The western half of the county lies upon a very level plain which is the bed of an ancient lake named, by Mr. Upham, lake Agassiz. The surface of the table-land is mostly rough, being an irregular arrangement of abrupt hills and intervening valleys, many of them occupied by lakes.

Drainage. Almost the whole drainage of the county is by way of the basin of the Wild Rice river, which flows westward through the centre of the county from end to end. The slope of the west half of the county is so gentle that this stream bifurcates near Ada and discharges its water into the Red river by two channels,


M A R S H A L L C O U
R.L.W.
R.XLVIII.W.
R.XLVII.W.
R.XLV.W.
R.XLIV.W.
R.XLIII.W.
TWEST
THIEF RIVER FALLS
ROCKSTAD
ANGUS
BRAY
GREAT
Campbell Beach
ST HILAIRE
North
Grand
Marais
Drainage
Ditch
Gladstone Beach
EUCLID
P
O
NORTHERN
WYLIE
E. GRAND FORKS
NORTHERN
PACIFIC
HILLTOP
RED LAKE FALLS
ROCKWOOD
KEYSTONE
BUFFINGTON
GREAT
SHIRLEY
MALLORY
NORTHERN
FREEMAN
FISHER
HIXON
Red
CROOKSTON
DELONNE
GARMAN
GREAT
BURWELL
BENOIT
NORTHERN
TILDEN
MARIN
DUGDALE
R.R.
KITTSON
NEBY
NORTHERN
LEES
Maple
MAPLE BAY
RUSSIA
HOMES
Herman Beach
Tintah
Sand
FERTILE
BELTRAMI
Sand
Hill
R.
Ojatta
Beach
NEILSVILLE
KALMER
Marsh
ROLETTE
COLENSO
SUNDAHL
MARSH RIVER
HALSTAD
GARY
N
O
R
HENDRUM
ADA
Marsh
River
HEIBERG
Wild
Rice
PERLEY
BORUP
N O R T H D A K O T A
C L A Y C O U N T Y


GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.
POLK AND NORMAN
COUNTIES
BY J.E TODD
Explanation
Recent
Glacial
Alluvium and lacustrine
Delta and other modified drift
Till flat or undulating
Moraine
Kames
Beaches
Railroads
Fifty foot contours
Hundred foot contours
Roads
Contour Lines are shown approximately for every 50 feet above the sea
Note. Below the highest beach line the till is more or less covered by lacustrine deposits
R.XLIII W.
R.XLI W.
R.R.XLW.
R.XXXIX W.
T.154 N.
T.153 N.
T.152 N.
T.151 N.
T.150 N.
T.149 N.
T.148 N.
T.147 N.
T.146 N.
T.145 N.
T.144 N.
T.143 N.
L
K
M
A
N
River
Clearwater
River
Lost
R.
South
Fork
Clearwater
R.
EMARD
OVETIA
LINDSAY
STETIN
MENTOR
ERSKINE
OLGA
KING
WILLEWATER
McINTOSH
WOODSIDE
GOSSEN
FOSSTON
VALLEY
WINGER
HANSVILLE
COLUMBIA
LENGBY
RINDAL
FAITH
Twin Lakes
White Earth
BECKER COUNTY
MAHNOMEN

which lie in some places several miles apart. The Wild Rice river rises less than five miles from the Mississippi river. Its northern head being in Upper Rice lake in the northwest corner of T. 145–36, while the southern branch rises on sec. 29, T. 144–37; after flowing first southwest it turns northwest through the Lower Rice lake. The stream enters the county about six miles south of the northeast corner, thence it flows south of west, where it receives an important tributary from the Twin lakes, but its longest is from White Earth river. This stream rises in the southeast corner of the county in lake Tullaby and takes a short turn out of the county southward through White Earth lake; thence flows northwest, entering Wild Rice river at the northeast corner of T. 144–42, and between this again and Ada it receives five branches more than ten miles in length, and the longest more than thirty miles, which latter rises in the northern part of T. 146–41 and flows nearly due southwest. From Ada it takes a direct course northwest and enters the Red river about four miles south of the northwest corner of the county. About three miles east of Ada it sends a bifurcation southwest into the northern part of T. 143–47, where it joins the so called south branch of the Wild Rice and follows it west and northwest to the Red river. A little east of the junction the south branch is interrupted, and lost in the marshy character of the ground, for a few miles. Five miles north of Ada a small stream, over ten miles in length, also loses itself in the low ground.

Lakes. Almost without exception the lakes of this county occupy the three eastern tiers of townships, where they are quite equally distributed. These are on the surface of the table-land at a hight of 1,400 to 1,600 feet above the sea. There are twelve of them more than two miles in length. Those which have received names are the Twin lakes, in the southern part of T. 144–36 and Tullaby, which crosses the county line near the southeast corner of the county. Data have not been obtained concerning their depth. They show the usual characters of lakes upon glaciated areas.

Polk county topography. This county has a general slope toward the northwest; its highest portions are in the southeast corner, attaining a hight of 1,550 feet above the sea; while the lowest is near the northwest, where it is less than 800. The slope along the southern line resembles that already described in Norman county. Beginning with 1,550 feet in the southeast corner it descends to less than 1,300 within ten miles. Within the next twenty miles it declines a little, and at that distance it crosses Herman beach of lake Agassiz at an altitude of 1,150 feet. That along the eastern line does not often fall below 1,400 feet until it reaches the north line of T. 149, when it rapidly descends to a level plain surrounding Red lake, which has an altitude of 1,150 feet above the sea and continues at that level to the northeast corner of the county. The northern boundary lies mostly upon a plain descending toward the west less than 350 feet in its whole distance. About three-fourths of the county lie in the basin of the ancient lake Agassiz. The southeastern quarter lies upon the upland, which is a lower extension of that occupied by eastern Norman county. The descent to the west and north is less abrupt.

Drainage. The county lies almost wholly in the basin of the Red Lake river. It includes also the valley of the Sand Hill river upon the south. The Sand Hill river rises in a lake bed about six miles south of Fosston and runs westward zigzagging north and south through a range of seven or eight miles, making four principal bends in reaching the west side of the county. About twelve miles before it reaches the Red river it becomes dispersed in a plain, from which it gathers after a break of six or seven miles in a number of small rivulets which occupy the east half of towns 147, 148–48. This stream receives the only branch which is upon the north side in T. 147–44, 46. The Red Lake river rises in Beltrami county, enters Polk county near the middle of T. 152–39. It keeps a west-northwest course into the southern portion of T. 154–43, where it receives Thief river from the north and northeast; thence it keeps a nearly due south course to the centre of T. 151–43, where it turns sharply to the west and receives the main branch of Clearwater river in the centre of the next township west; continues southwest to the southeast corner of 150–46 about four miles east of Crookston; thence west-northwest to Red

river at the northeast corner of T. 151–50. It has a larger volume than that stream above the junction. As it enters the county its banks are low and the country swampy. Its course to Thief river is so gentle that a small steamer makes regular trips from Thief River falls to Red Lake Agency. Its banks at the junction with Thief river are thirty-five feet. Between the junction of Thief river and the Clearwater it passes over two prominent rapids, caused by the accumulation of boulders. One furnishes water power at Thief River falls and the other at Red Lake falls. At Red Lake falls it has cut a gorge about eighty feet below the plain. Between that point and Crookston it has gone out again upon the general level, its banks being no more than fifteen feet at the latter point. From the centre of T, 150–48 it sends out an old channel, northwest, known as *grand marais;* and from nearly the same point it receives a number of tributaries from the plain to the south. The volume of water in this stream is not subject to the fluctuations found in many of the rivers, because it is supplied from such a vast extent of marshy country.

Thief river is its first important tributary coming from the north-northeast and has but a course of five or six miles in this county. It has a breadth of fifteen or twenty feet and a depth of from one to three feet. Its lower course is broken by several rapids, though it is a mostly sluggish stream with muddy banks. Clearwater river, which enters at Red Lake falls, receives the whole drainage from the highland to the southeast. It has numerous branches, which will be spoken of severally.

Clearwater river rises just outside of the county, in the southwest corner of T. 147–38, at an altitude of about 1,450 feet. It describes from that point a long circuit toward the east, and enters this county in the northeast corner of T. 151–39. It there has an altitude probably less than 1,175. It flows nearly parallel to the principal course of the Red Lake river, through a marshy plain to the southeast corner of T. 152–42, there it turns abruptly south-southwest, into the northwest corner of T. 150–42, where it is joined by a short stream produced by the junction of Lost, Hill, and Poplar rivers. From that point its course is little north of west to Red Lake Falls. It receives a small tributary, locally known as Badger creek, three to four miles from its mouth.

Lost river also rises just outside of the county, in a large lake in the southwestern corner of T. 149–39. It also describes a circuit approximately parallel with the Clearwater; enters the county in the northeast corner of T. 150–39, from which point it runs nearly due west to its junction with the Clearwater. Its course in the county is wholly within a marsh, and it obtains its name from the fact that it is for several miles nearly hidden by marshy growths.

Hill river rises in the southeast corner of T. 148–39, passes through a large lake in the same township, turns first to the northwest, thence to the west, descending from the highland to the plain. It reaches the plain in the southwest corner of T. 149–40, thence flows to the northwest corner of that township, then it takes a west-northwest direction to its junction with Clearwater. South of Lambert in T. 150–41 it is eighteen to twenty feet in width and two to three feet in depth.

Poplar river rises in the southeast corner in the northeast township of Norman county; flows nearly twelve miles to the east, four to five miles east of Fosston; thence keeps a quite closely northwest course to its junction with the Clearwater. Poplar river, upon the plain north of McIntosh, is twelve to fifteen feet wide and two to three feet deep.

Badger creek rises in a lake through a marsh north of Irskine in the southern part of T. 149–42, and flows northwest to its junction with the Clearwater. Unlike the other streams mentioned, its course lies wholly upon the plain. A few miles before joining the Clearwater it is about ten feet wide and six to eighteen inches deep. Red Lake river next receives a small tributary from the north known as Black river. It rises near the north line of the county, and its whole course is in townships of range 45.

A watercourse, sometimes a stream, rises in the southeast corner of T. 154–46 and loses itself in the plain in the southern part of T. 153–47. The Snake river, whose main course is in the county north, enters this county in the northern part of T. 154–48, and forms a large marsh occupying the north half of the next township west.

Lakes and marshes. The plateau region occupying the five or six southeastern townships presents numerous small lakes, common to moraines, most of them less than a mile in length, though two to three surpass that limit. Upon the plain west between Badger creek and Sand Hill river are a number of large, shallow lakes. The principal one of these is Maple lake, which is a shallow lake about six miles in length and a mile and a half in breadth, which lies northeast and northwest across the northwest quarter of T. 148–43. It is formed outside of the ancient beach of lake Agassiz, which bounds it upon the west and north.

Another lake of curved and irregular form, covering four to five square miles, occupies the southeast corner of the same township. North of Erskine is another lake, represented as two miles in length, of similar character to Maple lake. North of the highland region, the plain covering the sixteen or seventeen northeast town-

ships of the county is usually occupied by swamps, sometimes open, in other places occupied by tamaracks. The west quarter of the county, that lying west of range 46, is usually occupied by swamps of a different character; the ground is a level formation. The principal vegetation is marsh grass. This area is not very distinctly marked but gradually changes into the dryer land further east; and is attended with the corresponding shortening of the grasses.

ALTITUDES IN NORMAN AND POLK COUNTIES.

The Great Northern Railway System—Main Line.

	Miles from St. Paul.	Feet above the sea.
Glyndon, station and crossing of the Northern Pacific railway,	235.3	925
Buffalo river, water, 908; grade,	236.9	921
Averill,	241.8	917
Felton,	249.6	915
Borup,	254.9	911
Wild Rice river, bed, 895; water, 900; grade,	262.6	909
Marsh river, water,	264.6	890
Ada,	265.2	906
Long lake, former channel of the Wild Rice river, then passing westward in the present course of Marsh river, water,	265.5	901
Lockhart,	275.0	893
Rolette,	276.7	892
Beltrami,	282.0	901
Sand Hill river, water, 895; grade,	282.5	903
Russia,	288.0	892
Kittson,	292.3	885
Burnham creek, water, 868; grade,	293.0	882
Carman, junction of Fosston branch,	298.0	877
Red Lake river, water, 833; grade,	299.3	863
Bluff north of Red Lake river, natural surface, 886; grade,	299.7	876
Junction with line to St. Vincent,	300.5	885
Beach of lake Agassiz, excavated for ballast, crest, 882; grade,	302.8	879
Fisher,	310.1	852
Grand Marais slough (former channel of Red Lake river), bed, 830; grade,	312.1	846
Mallory	317.5	837
East Grand Forks,	323.4	831
Red river, bed, 779; lowest stage of water in ordinary years, 784-786; highest stage in ordinary years, 800-820; extreme high water (in spring 1882), 828; grade,	323.9	829
Grand Forks, 324.5 miles from St. Paul by this line, but only 320.3 miles by way of Moorhead,	320.3	830

From U. S. G. S. bulletin No. 72, "Altitudes between Lake Superior and the Rocky Mountains," by Mr. Upham, we extract the following railroad levels, with comments, so far as they apply to these counties:

Great Northern Railway System—Fosston Branch.

	Miles from Carman.	Feet above the sea.
Carman, junction with the main line, near Crookston,		877
Burwal,	6.1	914
Benoit,	11.7	1,019
Beach, 15 rods wide; crest, 1,062; grade,	14.2	1,063
Beach, crest, site of Pembina trail, 1,066; grade,	14.3	1,067
This beach ridge is 12 rods wide; from its west base, 1,062; to its east base, 1,065.		
Beach, 15 rods east of the last crest, 1,069; grade,	14.35	1,068
Beach, crest, 1,092; grade,	15.6	1,089
Beach, crest, 1,114; grade,	16.9	1,110
This is a very massive beach ridge, having a descent of 18 feet westward from its crest in 50 rods, and 8 feet eastward in 30 rods (probably the Campbell beach. J. E. T.)		
Beach, crest, 1,120; grade crossing Duluth and Manitoba railroad,	17.4	1,116
Beach, crest, 1,142; grade,	18.1	1,138

	Miles from Carman.	Feet above the sea.
Dugdale,	18.2	1,138
Junction of a branch graded toward Pelican Rapids. On this branch—		
Sand Hill river, near centre of sec. 13, Garfield (T. 147-44) low water, 1,116; grade,	29.7	1,145
Summit, natural surface and grade,	33.0	1,195
Creek tributary to Wild Rice river, crossed in sec. 36, Strand (T.145-44), bed, 1,072; grade,	44.1	1,107
Wild Rice river in S. W. ¼ sec. 25, Wild Rice (T. 144-44), bed, 1,023; water, 1,025; grade,	49.8	1,091
End of located line, natural surface, 1,177; grade,	53.5	1,174

On line from Dugdale eastward.

	Miles from Carman.	Feet above the sea.
Crest of eastward ascent, grade,	19.3	1,163
The surface is 1,161 to 1,167 feet thence to 23.4 miles. Small beaches are crossed at 22.4 and 22.5 miles, with their crests respectively at 1,166 and 1,167 feet.		
Mentor,	23.7	1,167
Hay creek, one of the outlets of Maple lake, bed, 1,156; grade,	23.9	1,165
Maple lake, water,	23.9	1,169
Summit, natural surface, 1,169; grade,	25.1	1,171
Badger lake, water, 1,172; grade,	29.5	1,178
Erskine,	30.3	1,187
Morainic contour extends from 31.0 to 33.0 miles and is succeeded by a moderately rolling surface farther east.		
Ravine between two lakes, bed, 1,199; grade,	31.9	1,224
McIntosh,	36.5	1,218
Poplar river, bed, 1,200; water, 1,204; grade,	37.4	1.211
The next half mile east has a morainic surface.		
Fosston,	44.0	1,288
End of track-laying, November 20, 1888,	44.7	1,291
Summit near the east line of sec. 35, T. 147-39,	53.5	1,545
Lakes, three-fourths of a mile east and southeast from the last, the most southern being called Long lake,	54.2	1,485
Head stream of Clearwater river, bed (mud to depth of 10 feet),	56.1	1,439
Creek tributary to Lower Rice lake, bed, 1,466; bottom land, 1,469; grade,	61.8	1,466
Mississippi river (about 30 feet wide), bed, 1,371; water, 1,373; bottom land 25 to 50 rods wide, 1,376; proposed grade of bridge,	77.1	1,409
This crossing is in sec. 8, T. 145-35, eleven miles north of Itasca lake.		

St. Hilaire branch.

	Miles from St. Paul.	Feet above the sea.
Shirley, junction with St. Vincent branch,	305.8	900
Ives, crossing of the old Pembina trail,	314.4	986
This is on the Lower McCauleyville beach of lake Agassiz, which is cut 4 or 5 feet across its width of about 20 rods; crest of the beach ridge, 990 feet.		
Upper McCauleyville beach, crest, 997; grade,	314.7	993
Little Black creek, water, 975; grade,	315.4	987
Black river, water, 970; grade,	318.0	997
Campbell beach, crest, 1,019, 6 feet above the land next east; grade,	318.5	1,011
Beginning of nearly level grade eastward, natural surface and grade the same,	323.2	1,078
Thence a slightly undulating surface with indistinct Lower Norcross beaches, extends to St. Hilaire and the Red Lake river.		
St. Hilaire,	327.3	1,086
Red Lake river, about	327.3	1,065

Line from Thief River Falls through St. Hilaire to Red Lake Falls.

Notes furnished by Mr. Upham from the profiles of the Great Northern railway.

	Feet above the sea.
Thief River Falls, 7½ miles north from St. Hilaire,	1,130
St. Hilaire,	1,086
Red Lake river mill pond, water, 965; about 9 miles from St. Hilaire, grade,	985

	Feet above the sea.
Clearwater river, 10 miles, water, 949; grade,	991
Red Lake Falls, depot, 997; water in Clearwater river, close south of depot, above dam,	961
This depot is considerable lower than that of the Northern Pacific line.	

Northern Pacific Railroad System.

(Duluth and Manitoba Railroad.)

	Miles from Winnipeg Junct.	Feet above the sea.
Winnipeg Junction, Northern Pacific railroad, 226.6 miles from Duluth,	0.0	1,181
Buffalo river, bed, 1,150; grade,	0.5	1,172
Summit, natural surface and grade,	5.8	1,253
Ulen,	13.0	1,154
South branch of Wild Rice river, bed, 1,113; grade,	13.6	1,135
Upper or Herman beach of lake Agassiz, crest 1,141; grade,	18.6	1,135
Descent south from crest in 12 rods, 9 feet; descent north in 12 rods, 6 feet.		
Twin valley,	25.8	1,093
Wild Rice river, bed, about 985; grade,	27.8	1,010
Norman,	33.9	1,099
Herman beach, crest, 1,156; grade,	43.7	1,151
Sand Hill river, bed, 1,075; grade,	44.5	1,115
Fertile,	45.5	1,140
Kittelson creek, bed, 1,094; grade,	48.1	1,124
Herman (*b*) beach, crest,	49.3–50.0	1,152–1,155
Herman (*d*) beach, three places, crest, 1,118–1,119; grade,	57.0–57.8	1,116–1,117
Crossing of the Fosston branch of the St. Paul, Minneapolis & Manitoba railway,	57.1	1,116
Tilden,	57.3	1,116
Norcross beach, crest and grade,	61.3–61.6	1,101
Tributary of Badger creek, bed 1,033; grade,	64.9	1,045
Red Lake Falls, junction of spur track to station,	68.7	1,036
Red Lake Falls, station 0.6 mile from the main line,	69.3	1,035
Red Lake river, bed, 932; grade,	70.6	964
Summit, cutting 9 feet; grade,	73.0	1,011
Black river, bed, 939; grade,	75.9	974
McCauleyville beach, crest and grade,	76.6–77.8	993–992
Crossing the St. Hilaire branch of the St. Paul, Minneapolis & Manitoba railway,	78.3	977
Beach, crest and grade,	80.7	962–961
Beach, crest and grade,	81.4	954
South Euclid, crossing the St. Vincent line of the St. Paul, Minneapolis & Manitoba railway,	86.0	901
Buffington,	90.0	872
Junction of spur track to Keystone,	93.3	855
Lowest portion of this spur track,	94.6–95.9	853
Keystone,	96.3	855
Grand Marais slough (former channel of Red Lake river), bed, 813; grade,	101.6	828
East Grand Forks,	104.7	831
End of spur to river, East Grand Forks,	105.1	807
Red river, bed, 779; extreme low and high water, 784–828; grade,	104.9	831
Grand Forks,	105.4	834

GEOLOGIC FEATURES.

No exposures of bed rock have been found in these counties. Here as in the adjacent counties the formations belong to the Glacial period and Recent epoch. The deposits of the Glacial period consist of till, modified drift, and lacustrine deposits. The Recent deposits cannot easily be distinguished from those of the Glacial period. The lacustrine formations are graded from those which were formed in the vicinity of the ice-sheet to those deposited long after its retreat.

Deposits of the Glacial epoch. These consist, not only of those formed by the land ice, but also those formed by lake Agassiz during the existence of the ice-sheet.

Till. This formation, presenting features similar to those elsewhere described, covers the whole county, though not always at the surface. Judging from the few excavations reported, its thickness may be estimated from 100 to 200 feet; although this may include, as in the case of the Red Lake falls section, aqueous deposits formed before the advent of the ice-sheet in the region. Theoretically we should expect the pre-glacial lake Agassiz as well as the post-glacial, and boulders of the till to present the same characteristics as those found in North Dakota, and distinct from those in the Mississippi basin, in the greater abundance of white limestone. These have been so abundant in some localities as to suggest the occurrence of continuous strata in the vicinity, but no such have been found.

Till comprises the surface deposit upon the summit of the plateau of the eastern part of Norman county, and six of the southeastern townships of Polk county, where it is mostly morainic, and also the western slope of the same, where it shows the more even topography found inside of a moraine. It presents the usual features reported from Becker county.

Moraines. Distinct moraines are only found east and south of the ancient beach of lake Agassiz, or on the till area.

In Norman county a morainic strip passing east of White Earth Agency, from six to eight miles in width, extends northward through the eastern range of townships. It sends out a branch toward the southwest south of Wild Rice river through Ts. 144-40, 144-41, 143-42, and 143-43. This moraine passes down the slope of the plateau westward and extends to the edge of the lacustrine deposits, where its hills were noted by Mr. Upham in his study of lake Agassiz. North of Wild Rice river the surface is more even.

In Polk county a morainic strip of rather indefinite outline but five or six miles wide is in many places finely developed; it enters the county along the south line in the southeastern township, extends north through that town and turns northeast so as to leave the county along the east line of the township next north. This is scarcely distinct from another strip which may be said to enter the county from the east along the east side of T. 149-39, and extends westward, becoming narrow toward the west, so that it forms a very stony ridge nearly 100 feet in hight in the southern tier of sections in T. 150-40, and ends abruptly in section 31 of that township. Along the south line of sec. 27 of T. 150-40 there is a gap through the ridge which appears to mark an escape from underneath the ice of a subglacial stream which flowed southwest through section 34 and thence westward to Hill river and connects with the ancient beach of lake Agassiz, which forms a broad delta-like deposit in the northwest quarter of T. 149-40. This channel gives one the impression of that of an important stream. Near its southeastern side is a terrace forty to fifty feet in hight and a mile or more in width, which is pitted with depressed basins and lakes.

FIG. 1. VIEW ACROSS THE OUTLET, SOUTH 62° + EAST. TAKEN FROM THE POINT INDICATED BY FIG. 9, p. 105. (p. 105.)

FIG. 2. NEAR VIEW OF LAMINATED CLAY IN RAILROAD CUT, EAST OF RED LAKE FALLS. (p. 106.)

Opposite the west end of this moraine the beach formations are also pitted with small basins suggesting the action of ice and the impression left upon the writer, when the region was first studied, was that this moraine was formed contemporaneously with one of the upper Herman beaches of lake Agassiz. Mr. Warren Upham, who has studied the region more fully, however, considers the upper Herman beach as continuing along the north slope of this moraine, eastward past the gap already mentioned and on to the vicinity of Red lake. Whether the two views are reconcilable, remains to be determined by further investigation. Figure 2, plate F, and figure 1, plate G, illustrate this moraine and channel. East of Fosston the moraines abound in lakes from a few rods in width to a mile or more, and are interspersed with hills rising forty to sixty feet above the lakes in the irregular manner common to moraines.

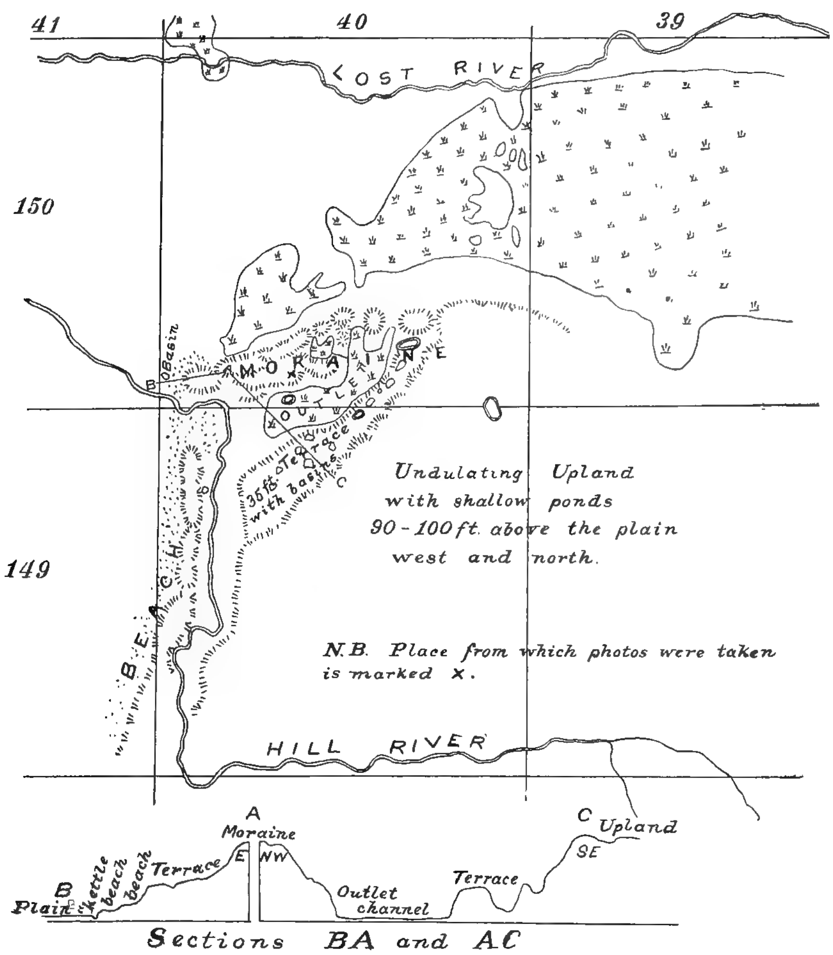


FIG. 9. MAP OF THE JUNCTION OF THE HILL RIVER MORAINE AND THE HERMAN BEACH.

Modified drift. This as elsewhere is shown along the streams in the form of terraces of gravel. The before mentioned terrace along the side of the ancient outlet in T. 149-40 belongs under this head. Also the terraces along all of the

streams, more particularly where they descend from the uplands to the plains toward the north and west. In general it is more clayey than in the Mississippi basin.

At Red Lake Falls, in the side of the gorge of the Clearwater the following section was noted:

(1) Slope.
(2) Eight feet, mostly yellow loam, stratified more or less, efflorescence below; bottom clearly defined.
(3) Seven and one-half feet of typical till, light bluish gray, or buff when weathered.
(4) Five and one-half to three and one-half feet of a band of boulders above, and laminated, pebbly clay below, sometimes mostly gravel; this layer extends up and down the river.
(5) Nineteen feet of light buff-colored till.
(6) Four feet bouldery slope to the level of the stream below the dam.

Upon the slope above this section appeared at various points, and particularly in the railroad cuts near by, several feet of laminated clay, in alternate layers of lead-colored and buff of very uniform thickness from one-eighth to one-fourth of an inch; the dark layers seemed to be a purer clay, while the thin light-colored layers showed imperfect traces of vegetable growth. The appearance of this clay is shown in fig. 2, plate G. The cuts along the railroad north of Red Lake falls and east of the town are mostly of this laminated clay, sometimes reaching below to a layer of fine sand or yellowish loam, sometimes with gravel intermixed. This laminated clay should, perhaps, be placed under the head of recent deposits, which may have accumulated in the shallow lake east and back of the beach running through the town west. The different layers made annually by accumulations correspond to the different seasons, and the lead-colored to the spring or period of rapid accumulation, and the light-colored to summer, the slight vegetation oxydizing the iron in it. Figures 2, plate G, and 1 and 2, plate H, illustrate this clay.

Beaches. The several beaches of lake Agassiz mentioned in the report of Clay county extend also across the western portions of these counties. Mr. Upham in his bulletin upon the subject (No. 39, U. S. Geol. Survey) gives the following facts with reference to these. In preparing the map great assistance has been gained from Monograph xxv, U. S. Geol. Survey, by the same author. The highest or Herman beach of lake Agassiz enters Norman county a little west of the southeast corner of T. 143-44 and curves north-northeast past Fossum postoffice to the vicinity of Wild Rice river near the centre of T. 144-43; thence it takes a north-northwest course to the middle of the north line of T. 146-44. The second Herman beach is traceable a few miles from the first and may be parallel with it. The Campbell beach extends nearly due north in range 45. The McCauleyville beach is usually near it. The details of their position are shown upon the map. Each of these beaches is usually attended with clayey flats upon the east sometimes attended with shallow basins yielding water while the west side is usually marked with quite abrupt slopes and a belt of bouldery ground one-half to three-fourths of a mile in width. The beaches are uniformly smooth with gently sloping sides. The surface is covered with a thin soil underlain with from one to two feet of gravel with several feet of coarse sand below.

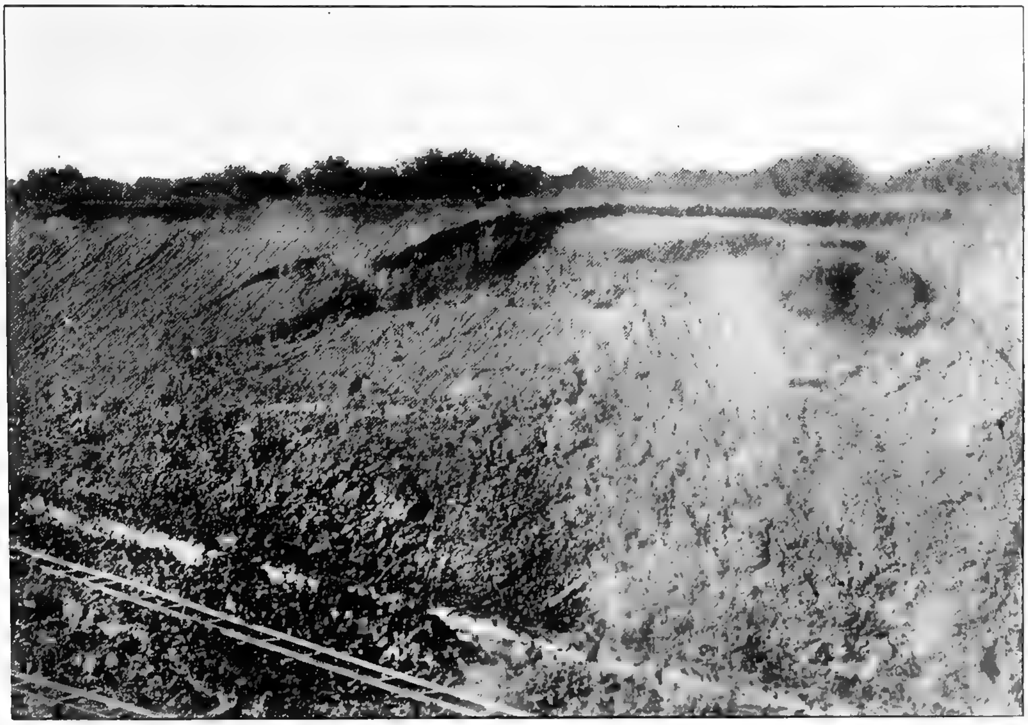


FIG. 1. A SLIP IN THE CLAY, CAUSED BY RAIN. (p. 106.)

FIG. 2. GENERAL VIEW OF CLAY-SLIDES, SHOWING GLACIER-LIKE MOVEMENTS. RED LAKE FALLS, LOOKING NORTHWEST. (p. 106.)

We will give the courses of the beaches more fully in Polk county. Of Herman beach, which marks the highest stage of the lake, Mr. Upham reognizes three subdivisions. The upper one of these enters Polk county in sec. 33, T. 147–44, and extends through the east edge of the southeast quarter of section 20 and to the west edge of section 27, where it has a typical ridge of gravel and sand with its crest 1,160 to 1,173 feet above the sea, there being a gradual descent from the west. The depression on the east is one-sixth to one-fourth of a mile wide, sinking six to ten feet below the beach. Farther east the land is moderately undulating, the till rising twenty to thirty feet above the beach bordering the Water and Sand Hill rivers. At the ford of the old Pembina trail in the west part of sec. 28, T. 147–44, the ordinary low stage is 1,071 feet. He says that when lake Agassiz was at its greatest hight, Sand Hill river brought into its margin a delta six miles long, south and north, and three miles wide, reaching from the upper beach to the west side of T. 147–44, and 146–44. This resembles the delta of Buffalo river at Muscoda, in Clay county. Upon this delta dunes have been raised up by the winds, probably before vegetation had been spread over it. The elevations of the highest points of these dunes, in order, from south to north, are approximately 1,190 to 1,180 and 1,200. The highest dune appears to be near the E. ½ N. E. ¼ sec. 30, T. 147–44. The upper Herman beach runs approximately from south to north through or near the northeast corner of sec. 4, T. 147–44, smooth gravel ridges in some parts hidden by scattered groves. Farther east is a large area of woodland. The upper beach in the southwest quarter of sec. 11, T. 148–44, forms the plain of stratified gravel and sand, one-fourth to three-fourths of a mile in width, east and west, 1,166 to 1,173 feet in altitude. This beach, on the south side of section 11, becomes a distinct gravel ridge of the usual character about twenty-five rods wide, with its crest at 1,173, bordered by a slough twenty to forty rods wide at its east side. About one-third of a mile farther southeast, and some fifty rods west of the southwest extremity of Maple lake, in section 14, same township, the elevation of this ridge is 1,175 to 1,178. The elevation of Maple lake on July 28, 1881, was 1,169 feet. The upper beach is a well marked gravel ridge on the east edge of the northeast quarter sec. 3, T. 148–44, and beyond this point through the next two and a half miles, curving from the north to the northeast and east across this to the upper beach of lake Agassiz is a magnificent exhibit, forming a massive, gently-rounded ridge of sand and gravel about thirty rods across, with its crest 1,178 to 1,186 feet above the sea. It is bordered on its southeast side by a tract of slightly undulating till ten to fifteen feet lower, mostly covered with small timber and marsh, yielding frequent sloughs and lakelets in its depressions. The top of the beach is not woody, but small trees and bushes encroach upon its slopes. A road extends along the crest of its curving portion for a distance of about a mile through sec. 36, T. 149–44. The marsh which borders the northwest side in the northeast

part of Maple lake shows a descent of five to seven feet northwestward, away from the lake; it has a width of one to one and a half miles. Maple lake is prevented from flowing in this direction by a beaver dam near the lake. There is a creek draining this marsh where it intersects the upper beach near the east line of the northeast corner of quarter sec. 27, T. 149-43. Here the beach skirting the north side of the marsh is a flat deposit of gravel and sand, one-fourth to one-half mile or more in width. The highest next to the marsh, above it rises five feet to eight feet in a moderate slope. Its elevation in the north half of sections 26 and 27 is one to two feet lower than the east, called the Attix ridge, "named from the settlers upon it," which lies some two-thirds of a mile farther north in the south half of sections 21 to 22. This belt of beach, gravel and sand continues six miles in a nearly due east course, and beyond that extends still farther eastward along the north side of a great tamarack swamp which begins in sec. 34, T. 149–42, and said to be about eight miles long. Maple lake and this tamarack swamp hold the same relation to the upper beach ridge which was a bar between it and lake Agassiz which now wholly or partially obstructs the drainage of these areas.

Here ended Mr. Upham's first investigation of the beach. He afterwards traced it at different points as far east as Red lake. The present writer found a beach developed along the west side of T. 149–40, running nearly due north into section 31 of the next township north, past the end of the moraine already described. In that portion it stands at the hight of fifteen feet or more above the low plains to the west. In passing northward from McIntosh it was not observed, probably because it had been removed by the action of Hill river. This probably corresponds to the upper Herman beach.

The second Herman beach, Mr. Upham says, is a rounded ridge of gravel and sand, ten to fifteen feet high, with a crest of 1,148 to 1,153 feet above the sea, and about three-fourths of a mile east of the old Pembina trail, in the W. ½ sec. 21, T. 147-44, extending half a mile north from the Sand Hill river to a cluster of dunes in the N. W. ¼ of section 16. He finds it again a broad low ridge of gravel and sand extending north-northeast through sec. 28, T. 148-44. From its southwest corner to its north line the northward continuation of this beach is a low flattened ridge, the western one of twelve parallel ridges of gravel below that of the upper beach extending northwesterly and northerly through or near the west edge of section 10, same township. Through the next three miles from section 3, same township, to the eastern part of sections 35 and 36, to the northwest corner of quarter sec. 25, T. 149 44, it is a prominent beach ridge with its crest 1,153 to 1,161 feet, somewhat steep on its east side, which descends ten feet to a belt of low land and marsh that divides from the parallel beach one-fourth to one-third of a mile east. The eastern parallel beach ridges are only ten to eight feet above the average elevation of the

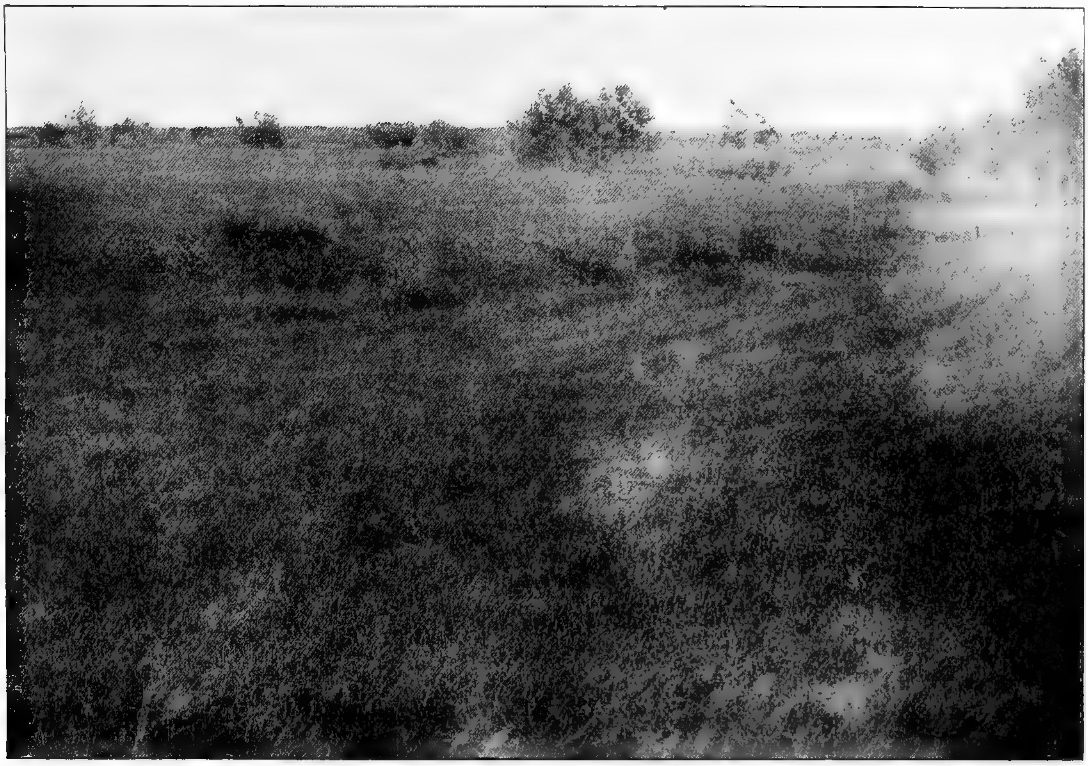


FIG. 1. A SUBMERGED MORAINE, LOOKING NORTH 40° EAST, NORTH PART OF SEC. 26, 156-43. (p. 109.)

FIG. 2. VIEW OF OLD BEACHES. SOUTH 30° WEST FROM SOUTH LINE OF SEC. 150-45. (p. 110.)

upper beach. It probably marks a slight fall in the water surface at this altitude, but as no corresponding beach formation has been found in Dakota it is neglected in the foregoing table of elevation of the beaches of lake Agassiz. It is clearly continuous eight miles, the first four miles extending northerly, the next four miles easterly. These parts are connected in sec. 25, T. 149-44, by a crossing curve with that portion of this beach, and it extends thence eastward, being known as the Attix ridge.

The third Herman beach Mr. Upham finds is a small ridge of gravel extending from southwest to northeast, eight to ten rods wide and rising four to five feet, crossed by the Crookston road in the S. W. ¼ sec. 23, T. 149-44, and seems to reach at least a mile away from the road. Its hight is 1,146 to 1,149 feet.

The fourth Herman beach is crossed by the road to Crookston and Red Lake Falls near the centre of the southwest quarter section 15. This is a well marked gravelly ridge, mainly single, but two-fold where crossed by this road. Its hight is 1,132 to 1,134 feet. A distance of a mile between this fourth Herman beach and the third consists of till.

It seems not improbable that the upper Herman beach ends as before suggested at the end of the moraine near the Hill river, and that the beaches observed farther east by Mr. Upham are continuations of the lower Herman beaches.

From four to five miles north from the fourth Herman beach, the road to Red Lake Falls crosses the Norcross beach in sec. 27, T. 150-44, where it is a belt of gravel and sand about one-half mile wide, extending from southwest to east-northeast at an elevation of 1,083 to 1,095 feet. There is a broad beach-like ridge, which was seen only from a distance, running in a north-northeast direction east of Beaudry or Perault station, for two or three miles in T. 150-44. It not improbably corresponds to some of the higher swells lying between Red Lake river and Clearwater river in their southerly courses. It seems not improbable that extending from the end of the east moraine toward the northwest there was an imperfect moraine accumulated in the bottom of the lake, which is the cause of the rapid descent of these streams in their southerly courses, and also the reason for that direction. This supposition is favored by the patchy character, as indicated not only in the soil, but in the distribution of vegetation. This is illustrated well in figure 1, plate I.

Mr. Upham suggests that some of the lower ridges of the Norcross beach appear along the railroad a little west of St. Hilaire station. It should be noticed, however, that according to his own statement, in his bulletin on the upper beaches of lake Agassiz, page 17, the surface is altogether too low; unless there is a declining of the ridges toward the north, which he does not note. There seems to

be evidence of such a decline by a comparison of the ridges along the Fosston and St. Hilaire branches of the Great Northern railway. In favor of the Norcross beach passing east of this point it may be mentioned that northwest of Thief River falls, near Excel postoffice, a beach, corresponding to the Tintah beach, comes in east of the Campbell beach.

Campbell beach. We have been unable to determine from Mr. Upham's notes whether in his bulletin No. 39, U. S. G. S., he recognizes more than one Campbell beach. In his Canada bulletin on "Glacial Lake Agassiz," he recognizes three at some points. Where we have observed this beach, there have been two closely related as in the northeast corner of T. 150–44 (Gentilly). A view of these beaches is given in figure 2, plate I. According to Mr. Upham's notes in his bulletin No. 39 on lake Agassiz, it enters the county near the middle of the south side of T. 147–45, and passes nearly due north to the south line of T. 150–45, when it turns nearly northeast to the northeast corner of that town to Red Lake river. It reappears near Wylie station on the St. Hilaire branch, running in a north-northwest direction, which it holds to the north line of T. 152–45, when it continues northward to the north line of the county. In T. 150–45 it has a well formed gentle arched ridge with a gravelly subsoil. It rises about six feet above the hight of the muddy flat on the east, and about forty feet above the long, canal-like slough separating it from the McCauleyville beach, whose crest at that point is only about eighty yards distant. Its hight above the crest of the McCauleyville beach is about thirty feet.

The McCauleyville beach. This, according to Mr. Upham, enters the county in company with the Campbell beach and follows it closely to Red Lake river. It there becomes separated from it and appears at Ives station, about four or five miles southwest of Wylie. It there is running west of north but soon turns more toward the east and approaches the Campbell ridge and passes the north line of the county not far west of it in range 45. Another beach whose correlation has not been determined runs nearly parallel with it a few miles west. All of these beaches have similar features. Their slopes are marked by lines of poplars and low bushes, while the area between is covered mostly with grasses and is more or less marshy. As Mr. Upham has already observed, they rarely, if ever, show a bouldery character. Upon the Campbell beach we found a limestone boulder about six inches in diameter, which is the only clear exception to the general rule, so far as known.

Bouldery stretches. In each case the inner or western slope of the beaches is quite abrupt and the edge of the plain on that side is usually clayey and strown with boulders. This belt of bouldery land may sometimes be a mile or more in width. The boulders are sometimes so numerous as to interfere seriously with tillage when dry enough to farm, and with mowing when used as hay meadows.

Clay flats. Extensive areas outside and remote from the beach are commonly covered with fine clay. This becomes marked just back of the different beaches and also in the western and lower portion of the lake Agassiz basin. The structure of the clays underlying these areas is given under the head of Modified Drift on a preceding page.

RECENT FORMATIONS.

These include the alluvial deposits along the streams and along the lakes upon the uplands in the southern part of the county. They resemble those of the adjacent counties next east. They are of comparatively limited extent in valleys; the broader basins connected with the main watercourses are sometimes filled with fine material forming considerable bottom land, a rich and usually easily tilled soil.

The deposits upon the Red Lake plain are such as are found in broad marshes, consisting largely of muck, and probably in some places beds of peat may be found. Along the lower courses of Red Lake, Clearwater, and Wild Rice rivers are extensive areas of fertile land sufficiently dry for easy tillage; in some places, especially where the land is very flat, the subsoil is very clayey.

The western half of the county lies within the old basin of lake Agassiz. While its terraces and beaches in the eastern portion of its bed are probably to be referred to the end of the Glacial epoch, the western quarter of the county is deeply covered with alluvial clays and loams of recent deposition, in part to be attributed to the accumulations of the lake in its last stages and in part to the Red river and its tributaries, before they had excavated their present distinct channels.

ECONOMIC FEATURES.

These in general may largely be inferred from the statements already made with reference to the surface and geologic features. A few additional points may be profitably considered.

Vegetation. The portions of these counties covered with continuous forests is limited on the west by a line running along the north slope of the highland region near the south line of T. 150 to the vicinity of Hill river; thence southeast, passing near Fosston and onward to the south line of Polk county, and thence a little west of south to the vicinity of White Earth Agency. In this region, which is occupied by morainic strips, considerable quantities of pine are found, also much valuable oak.

The eastern limit of continuous prairie, excepting of course the vicinity of streams and other limited local groves, may be drawn as entering the county from the north with the Campbell beach and following it to Red Lake river; thence it turns east-southeast to the edge of the highland about twelve miles north of McIntosh; thence south, east of Hill river to McIntosh, where it turns westward and follows the Herman beach around Maple lake and southward out of the county.

The area between these boundaries of continuous forests and continuous prairie is an irregular intermingling of groves and grass areas, the latter keeping the lower and wetter portions, while the former are found where the ground is slightly elevated. This belt is largely marshy and most of it is considered too marshy for occupation. On the plain west of Red lake these marshes are probably too deep for reclamation but in the area outside of the boundary of the old Red Lake Indian reservation is probably most of it capable of being drained, and, when necessity demands it, probably can be prepared for tillage. A portion of the prairie land traversed by the beaches which have been enumerated presents a variety of soils and surfaces, which, while not favorable in general for extensive farming is still adapted to various purposes which may be profitably followed in farming. The beaches afford pleasant and healthful locations for houses and for excellent roads. The clay flats where moist may be utilized for hay meadows and where dry may be tilled. The bouldery strips may be easily reclaimed by the gathering of boulders which may be utilized for building purposes.

The slopes of the beaches seem especially adapted for the growth of trees like the aspen, oak, elm, etc. The general slope of the region is such that drainage can be easily effected. West of the beaches the flat plain of the Red river, especially in its western portion, will for the present mainly be utilized for hay. The soil is generally a rich black loam, though in timber it is often of a light color.

Water-power. The slopes are sufficient and also the size of the streams for the development of valuable mill-sites along Hill river, Poplar river, and Badger creek, and particularly on Clearwater and Red Lake rivers between the points where they turn southward and Crookston. The altitude of Red river at the mouth of Thief river is nearly 1,100 feet. At Red Lake Falls only 940; at Crookston 850.

Clearwater river has a probably still greater fall between the points of its turn southward and Red Lake Falls. The valuable feature in both these streams is their slight fluctuations in level; for the range from low water to high in both these rivers at Red Lake Falls is only five feet. The other streams we have mentioned, from their smaller volume of water, can afford water power for only small enterprises. Wild Rice river, in Norman county, is also an important stream in these respects.

Artesian wells. The following interesting facts are culled from a letter furnished to the survey by Mr. Springer Harbaugh, published in the thirteenth annual report. Mr. Springer Harbaugh, of St. Paul, 1885, says:

"On Lockhart farm, in Norman county, in 1880, at 160 feet we struck an extraordinary flow of water. At a distance it had the appearance of a monument thirty or forty feet high. Other wells were sunk on his farm and all have quite heavy flows of pure semi-soft water.

"At Keystone farms in T. 151-48, since 1881 we have drilled eight artesian wells and they all have regular continuous flows of pure, good and semi-soft water.

"Water was struck on this farm at 95-120 feet, with one exception, where we reached water at 150. It is only upon this farm that the land is elevated to five feet above the surrounding country. We drilled several

test wells and found brackish artesian water at a depth of ninety feet, which we abandoned. We then determined to drill considerable deeper, and struck a pretty heavy artesian flow of milky, brackish water at a depth of 250 feet, which we also abandoned; and then selected a point on lower ground 1,200 feet distant, and found good artesian water at a depth of 100 feet. In drilling these wells we penetrated through the strata about as follows:

"Through the usual black loam from one and one-half to three feet; then through a light clay from five to seven feet; then through a blue clay, varying from 30 to 60 feet; then a stratum of hard pan; then sand and finally gravel, when water is generally struck. Between these strata we generally passed through intermediate seams of quicksand and also seams of gravel." (Ninth An. Rep., p. 166.)

At South Crookston Mr. E. S. Corser bored to a depth of 190 feet, "penetrating through the blue clay, in coarse sand or fine gravel, affording sweet cold water, quite soft, which rose ten feet above the surface through a three-inch pipe, at the rate of three pailfuls per minute."

From a general statement made by major Powell, director of the United States Geological Survey, in the eleventh annual report, part ii, page 267, we find that in Norman and Polk counties there are numerous artesian wells, all, with few exceptions, furnishing copious supplies of fresh water. They are distributed as follows, with the depths corresponding:

Norman county.

	Feet.
Shirley,	200
Halstead,	250
Eight miles northeast of Halstead,	165–219
Ada,	217
Lockhart,	140
In the vicinity,	125–150
From Ada,	100–200

Polk county.

	Feet.
Near Kittson,	80–140
Colman,	190
Vicinity of Crookston (probably 100 wells),	165–240
Fisher (water alkaline and saline),	285
South of Angus (also alkaline and saline),	253

All these wells pass through thin lacustrine and alluvial beds, then glacial drift (till) in which are water-bearing layers of sand and gravel. From this it would appear that probably saline waters would be found over most of the region by going completely through the drift clays to a depth of from 200 to 300 feet.

At Red Lake Falls a well has been bored over 400 feet. From the statement of the borer, Mr. Anderson, the following section is made:

(1) 47 feet of lacustrine clay, much of it laminated.

(2) 47 to 112 feet, clay, with small stones; water struck in limited quantities at forty-seven feet.

(3) 112 to 316 feet, sand and gravel, cement above the water for several feet; struck water at 118 and 316 feet, at last rose up to within forty-seven feet of the surface.

(4) 316 to 407 feet, clay without grit, presumably Cretaceous. The lacustrine clay of No. 1 is a deposit of lake Agassiz, and Nos. 2 and 3 are probably quaternary, the principal portion at least of glacial origin.

At Thief River Falls a boring had been carried down in 1893 to a depth of 258 feet.

(1) 225 feet "hard pan," probably till.

(2) 26 feet of sand and gravel.

(3) $1\frac{1}{2}$ feet of dark soft rock. No. 3 is possibly Cretaceous.

THE PROBABLE GEOLOGIC HISTORY OF NORMAN AND POLK COUNTIES.

Of the pre-glacial history we need say but little. The area was probably under the sea as late as the Fort Pierre epoch of the Cretaceous. It is not unlikely that

Silurian rocks also may be encountered in deep borings. After the retreat of the sea, in the Tertiary age the drainage very likely was toward the north, as at present. Toward the end of the Tertiary the drainage toward the north very likely became less abrupt because of the continental elevation toward the north and east. So far as yet known no buried channels of the streams of that time have been discovered but it is not unlikely that deep borings, especially in the southeastern portion of this area, may reveal the existence of such.

The Quaternary history. The following explanation is of course offered provisionally and as a means not only of fastening in mind the facts already given by arranging them about theoretical principles, but also to awaken interest for the testing of the theory and the consequent discovery of additional facts.

It is agreed by all students of the subject that the ice which occupied this region came from the north and northeast. From what was said concerning the geological history of Hubbard county it will be understood that the ice was independent in its movements from the ice lobe which occupied the upper Mississippi region. This at least was true in the later part of its history, which has left its impress most distinctly on the present surface of the country. The great lobe of ice which occupied the Red river valley, it will be remembered, moved southward and was divided by the eastern coteau into the western lobe, which crept down the James river valley, and the eastern lobe, which passed down the Minnesota valley into central Iowa.

In its recession we suppose that it had periods of halting and possibly advancing for a short distance, which has, as before explained, resulted in the accumulation of moraines. Between the Red river lobe, as we may call it, and lake Superior lobe, which occupied the upper Mississippi region, there was at one time probably no distinct separation upon the surface of the ice-sheet, but as they melted away their margins very naturally would be more and more separated along the hight of land or ridge forming the divide between the Mississippi basin and that of Red river. Along these separating margins there would be accumulated morainic material. This would, as each lobe gradually retreated, tend to form contemporaneous pairs of moraines or long slender v-shaped moraines, one branch of which should belong to the Red river lobe and the other to the lake Superior lobe. Between the pairs of these different moraines there would naturally be a great escape of water toward the south and the incidental production of much modified drift in the form of ridges, knolls, and gravel plains.

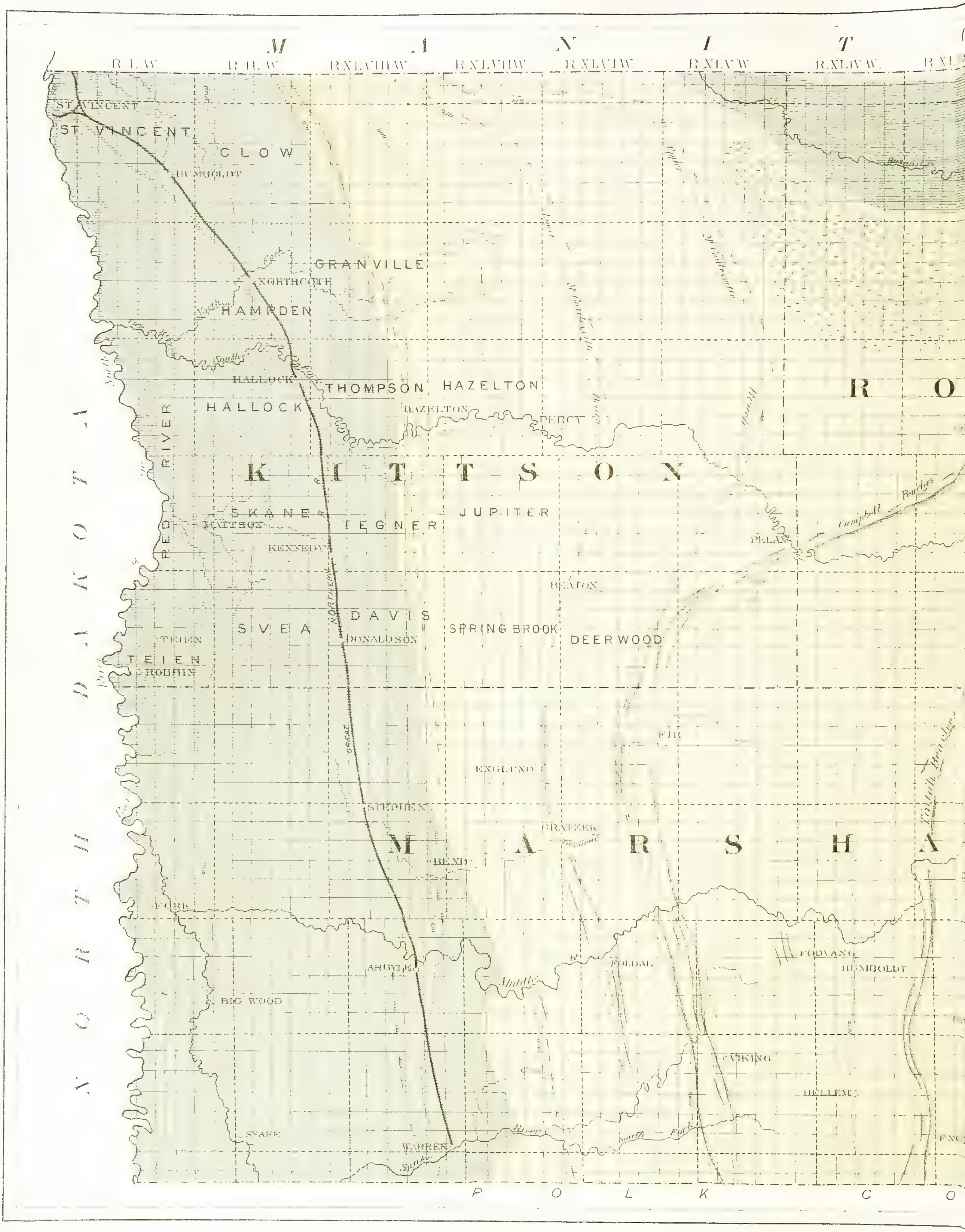
With this general conception we conceive that the first portion of this area, which became uncovered in the retreat of the ice, was in the extreme southeast corner of Norman county, and outside of the morainic strip which occupies the eastern range of townships in that county and turns southwest past Twin lake and

White Earth lake. While the Red river lobe was forming that moraine, the lake Superior lobe is conceived to have been forming the morainic strip, to be described later in the discussion of Beltrami county, which runs southeast from the lower Rice lake, past lake Itasca, into Hubbard county. These two moraines were probably separated from each other, although gradually approaching as far north as the head of Clearwater river. At this stage the water escaping from the slopes of the two ice lobes traversed the southeastern portion of Norman county and passed southward down the upper course of Otter Tail river.

Formation of the Wild Rice moraine. Next we notice the stage when the western ice-sheet was occupying and forming the moraine which runs west of southwest, south of the Wild Rice river, joining the upper Herman beach in T. 143–43. At that time circumstances permitted the water from its eastern edge to escape westward down the south branch of Wild Rice and Buffalo rivers to Muscoda. We may suppose that it was the time of the accumulation of the delta of that river at Muscoda. It may be objected to this interpretation that the Herman beaches which Mr. Upham associates with that delta may be traced farther north than this moraine, but it will be remembered that the beach was not continuously traced across the Wild Rice river, and from the margin of variation in the course of the beaches and the fragmentary representation of them, it seems not improbable that this theory may be reconciled with the facts.

The stage of the Hill River moraine. It will be remembered that a suggestion has before been made in connection with the junction of the morainic ridge in T. 150–40 and the high beach prominently developed there, that the ice may have occupied the moraine while the beach there present was forming. If that supposition is correct, we may conceive that the ice-sheet at that time had vacated the whole area under consideration except fourteen or fifteen townships in the northeast corner. It can be readily understood that the ice when confronted with an extensive lake should show a deeply reëntrant angle along the water front. This would be the deeper the slower the movement of the ice, and it seems not improbable that at this stage there was very slight motion of the ice-sheet, because of the stagnation of its fountain head on the north. We may therefore suppose that when the ice was in contact with the moraine in T. 150–40, the front of the ice, where bordering the lake, turned northwest and north in a more or less regular curve, passing the north line of Polk county somewhere west of Thief river. There would, of course, be a much more rapid melting and consequent recession of the margin of the ice in the lake, and the moraine less prominently developed from the accumulation of debris. The peculiarly stony character of the till along the southerly courses of Red Lake and Clearwater rivers, which has resulted in their very steep descent, together with their very shallow basins found along the strip,

seem to favor this view. Moreover, in this way could we find the most satisfactory explanation of the ancient channel, before noted, in the northern portion of T. 149–40. During that stage the drainage of the ice from the southern edge of the lobe which lay along the present southern slope of the Red Lake basin would have escaped largely by that channel. The fact of there being no boulders upon the beaches of Lake Agassiz would seem to be fairly explained by the supposition that the ice was mainly stagnant during this period of its recession and formation of its beaches. As a result of this, few floating bergs of ice would be detached from the ice. Moreover, in case masses burdened with drift were detached, the chances of the coarser material being raised to the hight of the beach would be slight.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ST. VINCENT
ST. VINCENT
CLOW
HUMBOLDT
GRANVILLE
NORTHCOTE
HAMPDEN
HALLOCK
THOMPSON
HAZELTON
HALLOCK
HAZELTON
PERCY
R O
RED RIVER
K I T T S O N
SKANE
MATTSON
TEGNER
JUPITER
KENNEDY
PELAN
Campbell
Beaches
BEATON
DAVIS
SVEA
SPRING BROOK
DEERWOOD
DONALDSON
TEIEN
TEIEN
ROBBIN
NORTHERN
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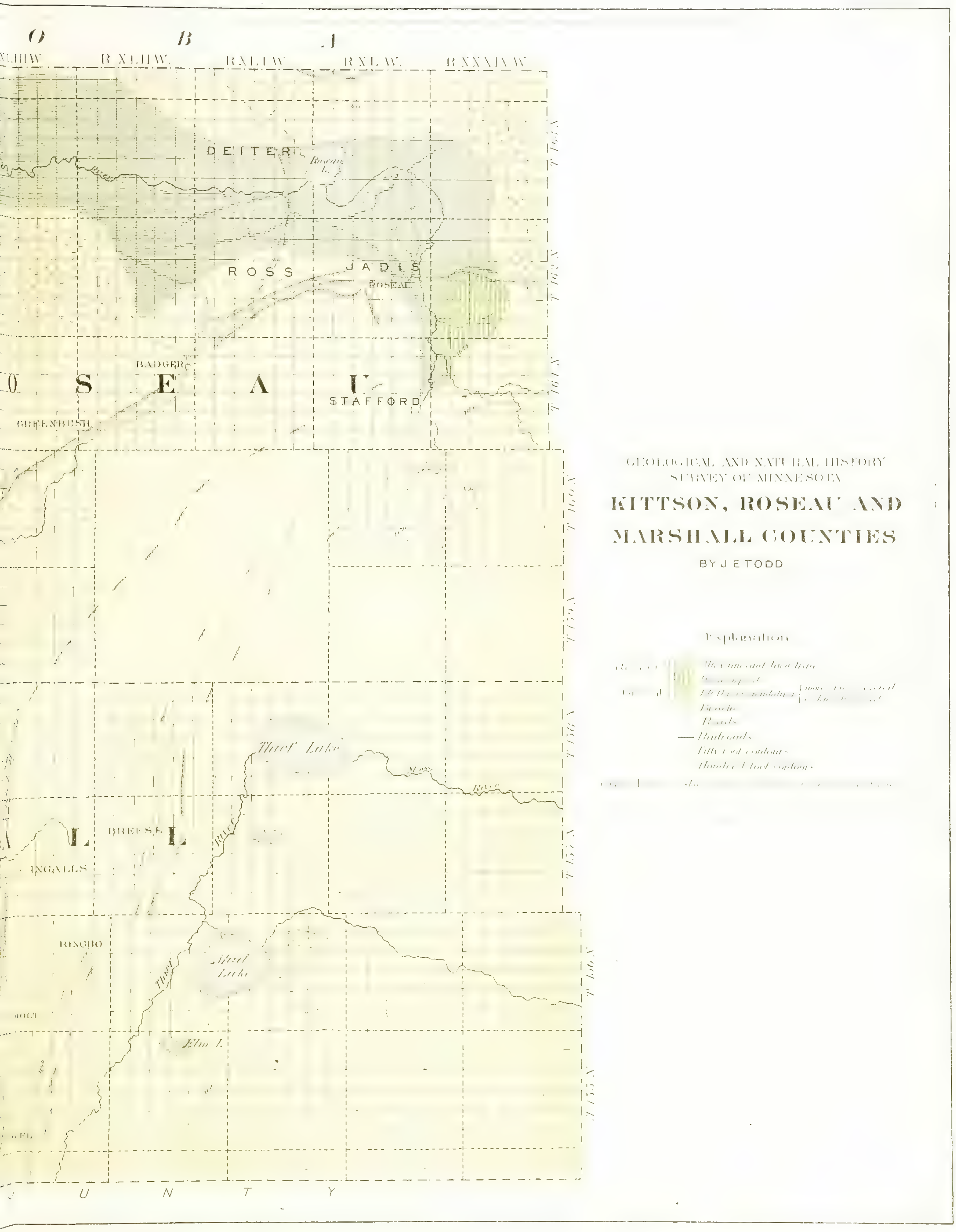

GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA

KITTSON, ROSEAU AND MARSHALL COUNTIES

BY J. E. TODD

Explanation

Railroads

CHAPTER VI.

THE GEOLOGY OF MARSHALL, ROSEAU AND KITTSON COUNTIES.

By J. E. TODD.

SURFACE FEATURES.

These three counties occupy a rectangular area in the extreme northwestern corner of the state (plate 63). They are very similar in situation, character of the surface and altitude. They all lie within the basin of lake Agassiz.

Our knowledge of this region has been derived from several different sources. It has been briefly alluded to by writers connected with parties sent out by the general government, also by Mr. Warren Upham in his work upon lake Agassiz. Our personal acquaintance has been confined to a trip, visiting Thief lake and the central portion of Marshall county, and a trip along the main route from Stephen to Jadis, and also a flying trip along the railroad. Several facts have also been derived from some of the annual reports of the survey.

MARSHALL COUNTY.

Marshall county is of rectangular shape, seventy-two miles by thirty, therefore containing about sixty townships. It is bounded on the south by Polk county, on the east by Beltrami, on the north by Roseau and Kittson, on the west by North Dakota, the Red River of the North forming the boundary. The surface is quite even, hills more than twenty feet in elevation above the general surface being unknown. It is largely covered with marshes and shallow lakes. The region east of Thief river is perhaps half covered with scattered groves of timber; all the rest, with the exceptions of the narrow strips of timber along streams and beach ridges, is covered with grass. According to the estimate published in the first volume of the final report, Marshall has 1,675.04 square miles, of which 1.4 square miles are said to be water. That the latter statement is a mistake may be readily shown by pointing out the existence of Thief lake, which must cover when at normal hight a surface of eight or nine square miles, of Mud lake, covering five or six, Elm lake, more than one square mile, while half a dozen small lakes may aggregate two square miles, making a sum total of more than fifteen or sixteen square miles.

Drainage. The drainage of the county is divided into two basins by a low ill-defined swell running parallel with Thief river and two or three miles from it. West of that line the slope is quite uniformly and gently to the west. East of it the slope, though mostly toward the west, has drainage into Thief river, which conveys it to the southwest into Red Lake river.

The principal stream of the eastern portion is Thief river, which flows in a narrow trough rarely exceeding twenty feet in depth and of little width beyond that of the stream itself. Its descent from Thief lake is considerable, as indicated by several rapids formed by boulder bars. The stream rises in Thief lake and keeps nearly a straight course south-southwest. It receives the outlet of Mud lake and enters into Red Lake river near the southern line of the county.

Its main branch is Moose river, which, in fact, might be called the upper waters of the first stream. This is a sluggish stream which rises in the swamps a little east of the county line, flows a little west of north into the east end of Thief lake. A similar stream known as Mud creek rises and flows in a similar direction about twelve miles south of Moose river, to the northern corner of T. 156-41, where it turns southwest and enters Mud lake on its northeast side in T. 156-40. It is a sluggish stream twenty feet wide and two or three feet deep, with banks of gravelly clay three to five feet high.

Thief lake occupies eight or nine square miles in the southwest corner of T. 158-40, and in the southeast of the next township west. Its north and east sides are timbered marsh; on the south and west is farm land lying ten or fifteen feet above the lake. Mud lake is surrounded by open marsh or quagmire on every side. It is of circular outline. The centre of the west line of T. 156-41 is near the centre of the lake. It is between two and three miles in diameter. Approaching it from the southeast is a shallow channel known as Little river, occupied mostly with small elongated lakes running toward the northeast and approximately parallel with Red Lake river. Southwest of Mud lake is another cluster of lakes lying approximately parallel with Thief river, which runs two or three miles west. There are no lakes west of Thief river.

The streams in the western portion of the county are Snake, Middle, and Tamarack rivers. The first rises in T. 156-45, and flows southwest nearly to the south line of the county, where it receives the waters of the South fork coming from the east; thence flows west past Warren, loses itself for a time in a swamp about eight miles west of that place, then follows a channel nearly parallel with Red river but converging toward it and entering it at the northwest corner of T. 157-49. Its upper portion is dry much of the year.

Middle river rises in a swamp a few miles west of Thief river near the northern corner of T. 157-42, flows southwest into the north portion of T. 156-44, thence

describes a curve to the north and again west-southwest to the vicinity of Argyle, where it is following a west-northwest direction, which it keeps until it enters a marsh about eight miles from that place. From this marsh the water apparently gathers into the lower course of Snake river as before described. It has running water in most of its course. At ordinary stage it is one to five yards wide and from six to twelve inches deep.

Tamarack river, as far as known, rises in the eastern half of T. 158–45, keeps a general direction west into the middle of the township, thence south two or three miles, then takes a general course with many crooks, northwest past Stephen, which course it keeps until it enters a swamp four or five miles from that place. About seven miles west from the point of its disappearance a stream gathers from that swamp and after a course of three miles enters a river in T. 158–49. It is twenty to thirty feet wide and about one foot deep, where it is crossed by the Pembina trail.

The highest portion of the county is probably a little west of Thief lake. The altitude of Thief River Falls depot, according to railroad levels, is 1,135 feet, which is not more than ten feet below the highest points around. The altitude of the before mentioned land near Thief lake is probably not more than 1,175.

ROSEAU COUNTY.

Roseau county derives its name from Roseau river, which drains most of the county. It is bounded on the south by Marshall county, on the east by Beltrami, on the north by Canada, on the west by Kittson. It is bounded on all sides by artificial lines and has a rectangular outline. Its length east and west is thirty-six miles, and its breadth north and south a little more than thirty. It consequently comprises about thirty-one townships or about 1,116 square miles. It includes but one considerable lake, viz.: Roseau lake, covering four to five square miles, in the west half of T. 163–40. It is occupied largely by swamps, especially in the northwest corner where three or four townsnips are included in "the great muskeg." The general slope of the surface for the whole county is toward the northwest. Near the Roseau river, where the course is toward the north, the slope is quite considerable and elevations of thirty to fifty feet occasionally appear near the streams, which are more marked where the stream traverses ancient lake beaches. One of the most conspicuous of these beaches begins near Jadis, near the centre of T. 162-40, and continues in a broad ridge west-southwest in a quite direct line past Badger to the west boundary of the county near Pelan, near the southwest corner of T. 160-44. Further description of this beach will be found in a later paragraph. There are probably other beaches. This ridge is bounded by swamps most of the distance. A stream breaks through it near Badger postoffice in sec. 12, T. 161–42, and after a course of

three or four miles loses itself in "the great muskeg." A somewhat similar sluggish stream, the head of the south branch of Two rivers, with quaking banks, follows the south side of the ridge and breaks through the ridge near Pelan. The eastern row of townships is traversed by the numerous branches of the Roseau river, which have worn channels from ten to thirty feet in depth below the surrounding country. The region from Jadis to Roseau lake is a low fertile alluvial plain covered with luxuriant grass. The Roseau river and the before mentioned ridge are bordered by considerable timber, some of it containing valuable pine. West of Roseau lake the stream enters "the great muskeg" but it keeps its course through and passes from this county to Kittson near the northwest corner. The highest part of the county is doubtless in the southeast corner.

KITTSON COUNTY.

This county, the northwestern-most of the state, is also nearly rectangular. A little more than five townships in breadth north and south and nearly seven east and west. It may be estimated to include an equivalent of thirty-six townships, or about 1,290 square miles, of which, perhaps 1.5 square miles are water, formed by two lakes in the northern part of T. 159–45. The surface of the county is prairie except in the vicinity of streams and lake ridges.

Drainage. The county is almost entirely drained by the stream known as Two rivers. This evidently obtained its name from the fact of the old Pembina trail crossing the main branches of the stream a little above their junction. The south branch, which is the main one, rises, as before said, in Roseau county and enters Kittson near the southeast corner of T. 160–45. It is there about twenty feet wide. It takes a course northwest at right angles with the beach-ridge, through which it has broken, which course it continues to the middle of the west side of T. 161–45, thence in a general westerly course it passes into the southwest corner of T. 161–48, where it turns north-northwest, receives the middle branch which has nearly a direct course from a point twenty miles east, thence passes north of Hallock, receives the north branch about eight miles west of that place and continues its course, entering the Red river at the northwest corner of T. 161–50. Near Hallock it is twenty-five to thirty feet wide, with banks fifteen feet high. The north branch of Two rivers rises in the south part of T. 163–46, and keeps a nearly direct course to its junction with the main stream, turning northward past Northcote. A small stream rises in the east side of T. 160–47, passes west into the next township and turns northwest as if to enter the south fork of Two rivers but is represented as sinking about two miles before reaching it.

The four southwestern townships of the county are drained by a much branched sluggish stream, which empties in Red river near the centre of T. 160–50. It is

understood that the northeast townships of the county lie in "the great muskeg," along the Roseau river, which, as before stated, enters the county from Roseau near the Canada line, and after flowing about six miles in this county passes into Canada in the fragmentary T. 164–45. From this it follows that the highest portion of the county lies in the southeast corner, where the altitude is estimated from the ancient beach to be nearly 1,050 feet, and the general slope is toward the northwest, where the lowest point occurs near St. Vincent, where it has an altitude of 787 feet. The surface of the county presents no abrupt elevations except in the close vicinity of the streams, where banks are rarely over fifteen feet. Where a stream passes through an ancient beach, as near Pelan, a difference of eighteen to twenty feet is found.

ELEVATIONS.

The three counties considered in this section are traversed by but one railroad, and the streams are not of sufficient importance to have called for surveys, therefore the authentic data concerning the elevations of the surface are few. From the St. Vincent branch of the Great Northern railway we have the following:

	Miles from St. Paul.	Feet above the sea.
Warren,	329.8	853
Snake river, water, 838; grade,	330.2	855
Argyle,	339.6	845
Middle river, bed, 828; water 831; grade,	340.2	842
Tamarack, bed, 811; water, 814; grade,	347.7	827
Stephen,.	348.1	827
Donaldson,	356.6	826
Kennedy,	361.4	825
Hallock,	370.5	815
South branch of Two rivers; bed, 791; water, 800; grade,	371.7	813
Northcote,	376.1	802
North branch of Two rivers; bed, 778; water, 784; grade,	376.5	798
Humboldt,	382.9	792
St. Vincent, switch of line from Emerson-Winnipeg,	389.2	787
St. Vincent depot,	390.2	787
Red river at St. Vincent; bed, 739; extreme low water, 748; high water in 1866, 782; usual water, 753; extreme high water 1882,	390.2	788
Grade on international boundary,	391.2	790
Red river high water, 1882,	391.2	786.5
Emerson, on branch of Canadian Pacific,	391.3	790

Elevations along the Red river.

At mouth of Red Lake river, Grand Forks, bed, 779; extreme low water and high water, 784–828; range, 44 feet.
Mouth of Turtle river, sec. 11, T. 154–51; ordinary low water, 778.
Akton, 2.5 miles north from the mouth of Forest river, ordinary, 773.
Mouth of Park river, St. Andrew, about 769.
Pelican bar, ordinary low water, 758.
Mouth of Pembina river and St. Vincent, bed, 739; ordinary low and high water, 753 and 782.

Estimated altitudes.

	Feet.
Of Thief lake, about	1,160
Of Roseau river at Jadis, about	1,015
Of Roseau lake, about	1,000
Of Roseau lake, according to the International boundary commission,	1,040
Of Roseau river at Pointe de Orme, according to the International boundary commission,	976
At the east end of Campbell ridge, west of Jadis, about	1,080

GEOLOGIC FEATURES.

The counties under consideration have great uniformity of structure. The older rocks or preglacial deposits are unexposed. Their depth below the surface is probably from 50 to 200 feet. The only report of older rocks is an uncertain one, which is as follows: A settler, who had been a quarryman, informed me that ten miles west of where Badger creek enters the "big muskeg" in the southern part of T. 162-44, he dug down four feet below the surface and found limestone four feet square without seams; how much more extensive he did not discover. Not far away in the ridge he said he saw flaky layers of limestone inclined. It is possible, if not probable, that these were boulders in the drift. Yet, from the fact that limestone appears abundantly in the drift in the Red river and Minnesota valleys, and that it is struck in the boring of deep wells, it seems not improbable that ledges of it may come near to the surface at the point stated. For a section of the older rocks consult a record of the St. Vincent salt well on a subsequent page.

GLACIAL DEPOSITS.

These consist mainly of the till. This is very rarely exposed because of the prevalence of later formations and the abundance of vegetation. It is known to lie near the surface, particularly in the southeastern portions of Roseau county and the eastern part of Marshall county. In the latter region irregular bouldery knolls, rising a few feet above the swamp, are not uncommon. The abundance of boulders on the lower side of the beaches, and also in very rare cases upon the beaches themselves, indicates the nearness of the till to the surface in such localities. In sec. 27, T. 156-44, which locality is a short distance west of an ancient beach, wells revealed only till, somewhat stratified at the top. This is probably generally true inside of high beaches.

Moraines. No typical formation of this class has been discovered in these counties nor should we expect it, when we remember that the whole of the region lies in the bed of lake Agassiz. From that fact it follows that no portion is free from the results of lacustrine action. In the discussion of Polk county it was suggested that a strip of country extending northwest from the moraine in T. 149-40, was really a moraine, modified by the lacustrine waters which attended the front of the ice-sheet. Instead of forming knobs and basins of typical form, the irregularity of structure is shown by irregularly arranged patches, that is, groves of poplar are irregularly interspersed with grassy meadows. The former being somewhat elevated and the latter frequently very wet. It will be remembered that this strip passes on the north side of Red Lake river north of Red Lake Falls, and extended northward, west of Thief river and Thief lake, to the north line of Marshall county. The dry land west of Thief lake seems to be a portion of this strip. Its slight

elevation above the surrounding country forms the low water-shed, already mentioned, a little west of Thief river. Though sand appears upon the surface quite generally, the subsoil is clay and frequently shows boulders. For reasons that appear more clearly in Beltrami county it is conjectured that this strip turns eastward north of Thief lake and connects with high land south of Lake of the Woods. Had the country been at all passable the southeastern portion of Roseau county would have been examined to ascertain concerning this fact.

No distinct traces of osars or kames have been found. We should at any rate expect them to be modified by lacustrine action. Reports have been given to the effect that a knob of some elevation covers four townships about ten miles south of Badger postoffice, which would be in the southeast corner of T. 160–42.

The lacustrine deposits. These cover the whole surface of these counties, except where the action of waves or undertow prevented. They consist of clay flats, bouldery strips and ancient beaches, the first being much the more prevalent, especially in the west portions of the counties.

Beaches. By reference to the reports on the counties farther south, it will be understood that the highest beach of ancient lake Agassiz, named by Mr. Upham the Herman beach, is divided into four or five different members. Toward the north, at Maple lake in Polk county, these members vary in hight through a range of forty-five or fifty feet. Moreover Mr. Upham discovers, from his examination of the hight of this beach, that this variation increases toward the north and east. It will be remembered that in the southern part of T. 150–40 a beach probably corresponding to the highest Herman beach is found connected with a moraine and also a drainage channel, or outlet through the moraine. The next group of beaches, known as the Norcross, seems not to be represented, unless in detached fragments east of Thief river not yet recognized, appearing in Marshall county along the east side of T. 155–44, and probably a portion of what Mr. Upham calls the Tintah beach. It is there double, the two members separating and uniting from time to time, rising ten or twelve feet in some cases above the surrounding country. Its course as determined passes northward to the northeast corner of said township, then turns northeast for a couple of miles, then turns to the east side of the township east of Humboldt and is found along the east side of secs. 31 and 30, T. 157–43; it there crosses Middle river and is believed to continue in a northern and northeastern direction. It is sometimes called Oak ridge because of the frequency of those trees along it.

The Campbell beach is much more conspicuous in these counties, and forms a most important feature. It has not been traced between Wiley station in Polk county and the east side of T. 156–46. That it is fairly continuous is probable from

its being followed by the old Pembina trail. It has been traced from the middle of the east side of the last mentioned township across Middle river, north by west, to Tamarack river, which it crosses near Fir postoffice, sec. 2, T. 158–46. At this point it forms a grand natural turnpike. It takes a due north course to the southwest corner of section 13 of the township north, thence east-northeast, crossing the south branch of Two rivers upon the county line in the east side of sec. 25, T. 160–45, then follows a direct course to Badger postoffice; east of which it crosses Badger creek on or near sec. 12, T. 161–42, and continues without further interruption to the centre of T. 162–42, about two miles west of Jadis, a lower attendant of it even reaching that place. It forms a perfect thoroughfare, it is grassy on its top, it is often eighteen to twenty feet in hight with a breadth of 600 yards and at several points is double or triple with sometimes cross ridges. At its eastern extremity it ends in an abrupt curve toward the south and very likely may be traced south parallel with or converging toward the course of the Roseau river south of Jadis. A ridge corresponding to it in hight is reported on the east side of the Roseau south of Jadis; and a short ridge corresponding is crossed by the trail from Jadis to Lake of the Woods in Beltrami county. To illustrate some particular points of its structure, several small diagrams are appended. These have not been carefully measured but represent the general plan correctly,

Upon this ridge a problematic feature was noticed in the form of straight, narrow ridges of gravel several rods in length and from 1.5 to 3 feet in hight. They lie upon the flat surface of the ridge and remind one, in appearance, of ridges found around lakes which have been made by the thrusts of the ice, either under the tension of freezing or when pushed by storms. The most notable examples are found about two miles east of Pelan and are shown in figure 10.

Upon the ridge a little north of Fir postoffice, one of these sharp ridges lies longitudinally, but in the other case they are transverse. Local tradition ascribes them to the Indians. They are said to be low fortifications, made somewhat after the fashion of rifle-pits. Nothing in their appearance would suggest such an explanation. The ground seemed to be of equal hight on both sides, nor can we conceive how their position could be of any advantage for defense, for they could be easily flanked. They may perhaps have been formed by thrusts of floe ice at some time when the level of the water covered the ridge, and yet this explanation is hardly satisfactory. This feature is illustrated in figure 1, plate J, and the adjoining sketch, figure 10.

The subsoil upon the surface of the beaches is gravelly and sandy. The slope toward the northwest is greater and usually more abrupt, but it is often quite abrupt toward the southeast. The ridge forms a natural dam to the waters finding their

FIG. 1. PECULIAR CROSS-RIDGES ON THE BEACH ABOUT THE MIDDLE OF TOWNSHIP 160-44. THE HIGHT OF ONE IS SHOWN BY THE WAGON WHEELS WHICH ARE JUST BEYOND IT. (p. 124.)

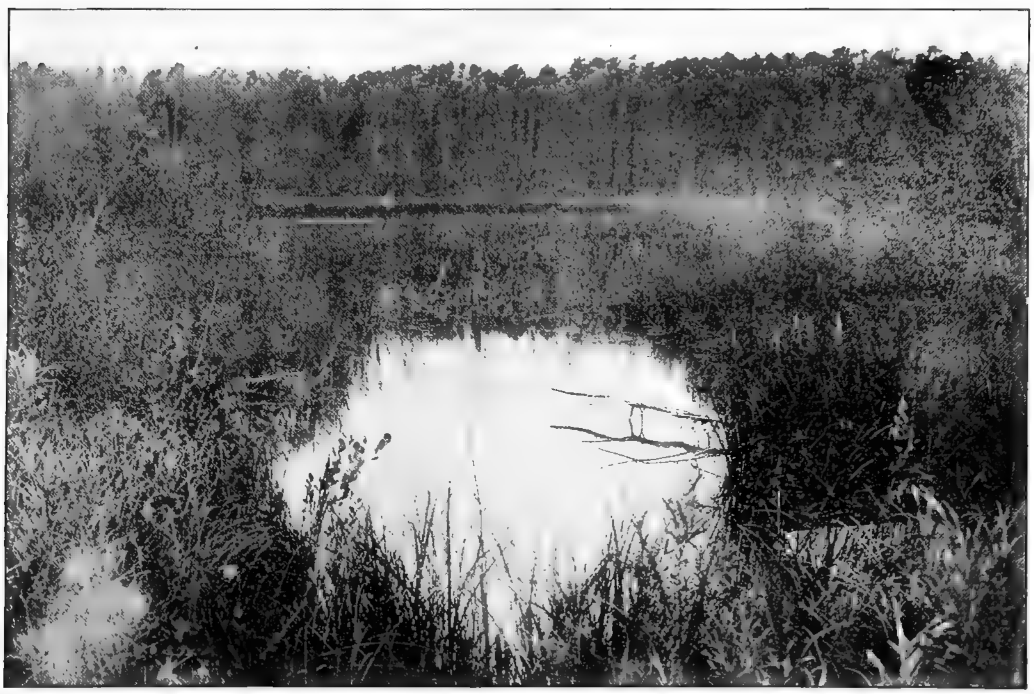

FIG. 2. VIEW NORTH, 46° WEST, FROM THE MOUTH OF THE CREEK ENTERING ITASCA LAKE FROM ELK LAKE. (p. 136.)

way down the slope to the northwest. As already stated, two gaps have been formed by the south branch of Two rivers and Badger creek. Very frequently, away from these gaps, there is a quagmire covered with coarse grass upon that side, and in T. 159–45 there are two lakes with open water of considerable extent shading off into a grassy swamp on the east and south. If the Campbell beach rises regularly toward the east, as Mr. Upham has figured in his work on lake Agassiz, and in Bulletin No. 39, U. S. Geol. Survey, the end of the beach near Jadis should be about 1,075 feet above the sea. This figure seems to correspond well with what is known of the surrounding country as reckoned from Lake of the Woods.

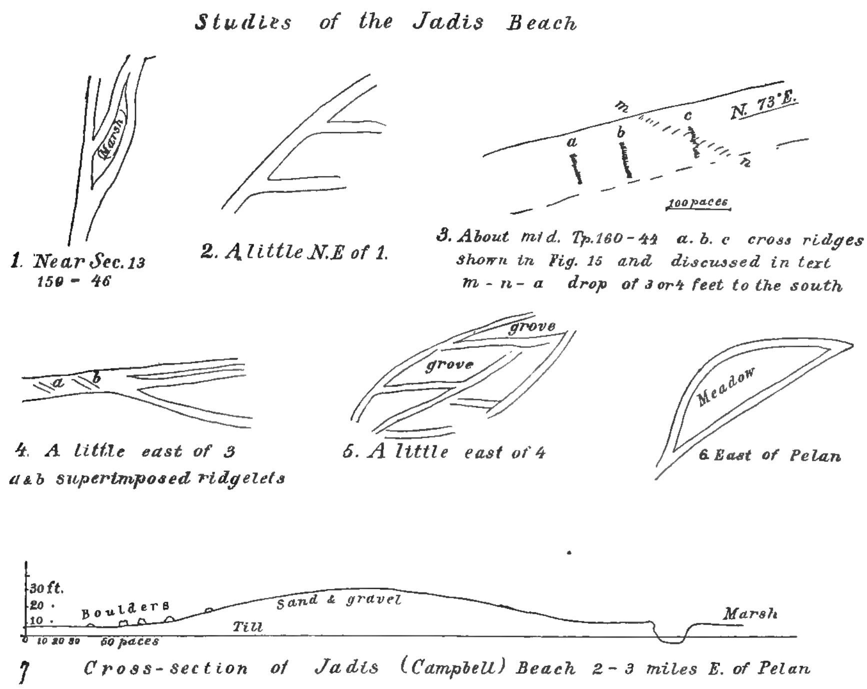

FIG. 10. PECULIARITIES OF THE JADIS BEACH.

The McCauleyville beach, it will be remembered, is found attending the Campbell beach southeast of Red Lake Falls but is separated from it at Ives station. It is found a few feet lower than the Campbell beach and a few rods from it where the latter appears on the east side of T. 156–46. It follows along side of it to the south line of T. 158–46, when it becomes obscured by the older delta of Tamarack river which is most prominently developed along the west side of that stream in the south central portion of the township. From the east side of sec. 9, T. 158–46, it turns north-northeast and approaches the Campbell beach again and attends it to the south line of section 12 of the township north. There it turns off to the north and northwest, forms quite an angle with Campbell beach and its further course is unknown. Another beach is noted consisting of three members, lying along the south side of Middle river on sec. 9, T. 156–46. This seems to have been considerably obscured by the delta deposits of Middle river, especially on the north side. The course has not

been traced for several miles but it appears again quite well developed in T. 158–47, and has been traced four or five miles through the east tier of sections of that township. It probably corresponds to the Blanchard beach, as it is called by Mr. Upham in his report on glacial lake Agassiz in Manitoba, p. 92.

Bouldery strips. The inner sides of the beach ridges are bounded generally by clay flats quite thickly strown with boulders, so much so as to interfere with tillage when dry enough to farm and for mowing when used as hay meadows. This feature is easily explained by the wash of waves and undertow when the adjacent beach was forming. In some places these boulders are so abundant as to suggest that floating ice may have helped in collecting them. It will be observed that if icebergs were floating in the lake, they would strand in such a way as to drop their boulders in shallow water near the beach. As Mr. Upham observed, boulders are rarely found on the beach itself. This may be easily explained by the work of the waves steadily heaping up the pebbles and sand so as to cover boulders that were either left in the glacial till or had been dropped as just explained from floating ice when the water covered that point. Sketch figure 10, 7 shows the common relations.

Clay flats. Extensive areas inside and remote from the beaches are commonly covered with fine clay; this is the case about Stephen, and I understand generally toward the middle of Red river plain. Quite extensive areas, just outside of the beaches, are also of this character. A description of the characteristic structure of this clay deposit is given in the report on Polk county. The accumulation must have gone on quite rapidly and to considerable depth in the deeper portions of lake Agassiz. In the Roseau valley a similar form was observed in a freshly dug well. A case was reported as follows: Near Roseau lake, eight feet below the surface, this laminated clay was struck, and was eight feet thick, then sand and pebbles prevailed for twenty-three feet, then the laminated clay which continued down 160 feet from the surface. At another point a well was dug 110 feet deep, all in this laminated clay, and from that depth the water rose to the surface.

Alluvial deposits. These are not particularly prominent in the region because the streams are not very vigorous, owing to the low and uniform surface of the country. These are found in limited extent along the principal streams, more particularly along the Roseau and Red rivers.

Under this head also may be included the ancient deltas of some of the streams formed at different stages in lake Agassiz. We have already referred to deltas in Middle river at the time of the Blanchard beach as well as of the Campbell, and to the deltas of the Tamarack at the time of the McCauleyville beach. Similar deposits are found around Pelan northeast of the gap in the beach, and on the east side of Roseau near Jadis.

The geological history of the area of these counties. This resembles in almost every respect that of the surrounding counties. With little doubt it was occupied by the sea in the early Paleozoic and in later Mesozoic time. It was covered with the continental ice-sheet in the early Quaternary and with the waters of lake Agassiz after its recession. The last portion to be covered with the ice was doubtless the northeastern corner of Roseau county, and the last part covered by the waters of lake Agassiz was the northwestern corner of Kittson. That there was a greater dip to the northeast when the streams first began to flow is suggested by the course of the Roseau river and by the old channel from the vicinity of Red Lake river to Mud lake. At one time perhaps there was drainage from Thief river and Mud lake west into the head of Middle river. Differential elevation to the northeast subsequently may have shifted the waters to the south into Thief river and Red Lake river.

Of the beaches, as Mr. Upham has shown, the McCauleyville and those higher were formed when lake Agassiz emptied to the south and the later ones after its waters began to escape to the northeast.

ECONOMIC FEATURES.

This region is covered mostly with grass, and extensive and excellent hay meadows abound along the Great Northern railway in the western part. Much of the surface further east is covered with swamps in which the grass is scant, or which are covered with moss. Very little of pine land is found. Considerable is reported along the upper waters of the Roseau, much of which doubtless lies in the eastern and southeastern portions of the county. Little if any pine is found in Marshall county. Tamarack, spruce, and cedar are abundant in many of the swamps in the northeastern portion of Marshall and the southeastern part of Roseau.

The portion particularly adapted for agriculture is the great valley of the Red river west and northwest of the Campbell beach, and the valley of the Roseau above and around Roseau lake. From the vicinity of Jadis to the lake the surface lies beautifully for cultivation and is very fertile. The valley is from two to ten miles in width.

Wells. In the eastern portion of this region water is easily obtained near the surface, and deep wells are unknown. Reference has already been made to the deep wells in Roseau valley. Similar relations exist in the valley of the Red river, northwest of the Campbell beach. A number of flowing wells have been obtained by piercing lacustrine and drift clays. Wells of this sort have been obtained at Argyle, in Marshall county, at the depth of 150 to 180 feet. At Tamarack similar wells are obtained by going 74 to 218 feet, and at Stephen 220 to 300 feet. In Kittson county, at Donaldson, wells are 45 feet deep; at Kennedy, 95 feet; Hallock, 179 feet; near Northcote, 30 feet, and at St. Vincent, 165 feet. All of these,

except that at Hallock, furnish abundance of water which is saline. The difference of depth of these wells is probably due to different sand strata of the drift clays. It seems not improbable that the supply of water in the drift strata may be partly obtained from the Cretaceous strata which furnish water to the deep wells in Dakota.

The Humboldt salt well. The following is a section of the Humboldt salt well, which was bored near St. Vincent, in Kittson county, in the south half of sec. 35, T. 163–50, five miles east of the Red river, 4.5 miles from the international boundary. The altitude of the well is seven feet above the highest known flood stage of the river. It is particularly instructive concerning the oldest rocks underlying the region, and the thickness of the lacustrine and glacial clays. The following section is somewhat abridged from the thirteenth annual report of the survey. A map of the vicinity of the well may be found in the ninth annual report of the survey.

Section of the Humboldt salt well.

		Thickness, feet.	Depth, feet.
(1)	Subsoil 8 to 12 inches, black,	4	4
(2)	Lacustrine clay with lime concretions; it contains good surface water, and apparently varies in other places to a very fine sand,	12	16
(3)	The same as the last but more impervious, hence is more moist, darker colored,	124	140
(4)	Pebbly blue till. Salt water at 165 feet in small quantity,	30	170
(5)	Drift gravel and sand supplying an abundant discharge of salt water flowing over the surface. This is mainly gray sand but contains drift pebbles as large as an inch, mainly of sandstone,	10	180
(6)	Buff dolomitic limestone of grain and texture like the Lower Magnesian limestone of southern Minnesota,	120	300
(7)	Powder containing some small fragments of compact limestone of slightly reddish cast,	100	400
(8)	Fine reddish lime rock with some grains of white quartz,	75	475
(9)	Sand, rounded grains, reddish above and below but white for about 30 feet in the middle. The flow in salt water increased	71	546
(10)	Soapstone shale, slippery, red and green with some portions dark gray, contains white particles,	46	592
(11)	Greenish gray shale,	46	638
(12)	Washed grains, consisting mainly of rounded quartz and freshly fractured, angular opaque gray quartz. Numerous scales and masses of mica. It appears as if it were a greenish-gray, foliated, micaceous quartz-schist,	1	639
(13)	Washed drillings, consisting of angular quartz, black mica scales and angular grains of flesh-colored orthoclase and white feldspar, evidently one of the granites as seen at Lake of the Woods. Boring ceased at 644 feet,	5	644

Following are Prof. Winchell's comments on this well as published in the thirteenth annual report:

The Humboldt salt well in Kittson county.

It has been known for many years that copious salt springs existed in the valley of the Red river of the North. From their abundance several streams have been named, as Salt river, and "Rivière Salé." Some of these springs are in Dakota, some in Minnesota, and others, probably the most numerous and copious, are in Manitoba. Some of the earliest French explorers, notably Sieur Du Luth, mentions the fact that the Indians exhibited salt which they said had been obtained in the vicinity of certain lakes in the western prairies, said to be fifteen or twenty days' travel farther west.

Prof. Henry Youle Hind, in his report on the Assiniboine and Saskatchewan exploring expedition, in 1859, has summarized the principal facts respecting these springs and the salt deposits of the valley of the Red river of the North. They had been made known in Dakota and Minnesota by Prof. Keating in 1823, who accompanied

major Long to the "Sources of the St. Peter's river and lake Winnipeg." At that early date $500 had been made by a single individual from the sale of salt manufactured in one summer near Pembina. The country was so permanently and extensively saline that the characteristic *Salicornia herbacea* was found growing abundantly in its natural wild state, the only inland locality known west of the Onondaga salt springs, in New York.* In 1859 the manufacture of salt from springs in Manitoba was carried on profitably for the Hudson's Bay company, at Swan river and at Winnipegosis lake, the methods of manufacture being of the rudest kind.

South of the international boundary several deep wells have been sunk within a few years for the purpose of getting a supply of water for stock and farming purposes. Some of these have given an artesian overflow of brine. The first of this kind in Minnesota was sunk at St. Vincent, which is on the Red river of the North at the crossing of the international boundary. This well was 165 feet deep, and only penetrated the drift deposits, the greatest thickness being taken up with a fine lacustrine clay 112 feet in perpendicular thickness. Under this was found to be coarse gravel and sand which afforded a copious overflow of salt water. This water was not carefully analyzed, though Dr. Perley, at Fort Pembina, made tests sufficient to show it was a brine principally of chloride of sodium, but contained a considerable quantity of magnesium and calcium.

Recently another well has been sunk on the Valentine farm, at Humboldt, about six miles southeast from St. Vincent, on the line of the St. Paul, Minneapolis & Manitoba railway. This also gives a strong salt water, which rises under natural hydrostatic pressure several feet above the ground. The water is clear, and effervesces slightly on exposure to the air and the removal of the pressure.

The section penetrated by this well was the same as that at St. Vincent, but extends much deeper. The salt water was found to rise first from a bed of gravel and sand at a depth of 165 feet, but in small quantity. Between 170 feet and 180 feet, the flow of brine became very copious, rising from a coarse gravel and sand pertaining to the drift. The object of the well being to obtain water for the use of the farm, the drill was sunk deeper. It at once entered a dolomitic limestone. which was found to be 295 feet thick. This has a grain and color like that which is known as the St. Lawrence limestone in the Mississippi river bluffs. Beneath this was found a saccharoidal, siliceous sandstone of rounded grains of quartz, that still furnished a flow of salt water, which rose with still greater force. The drill then entered greenish and reddish shales, some of these being of a reddish-umber color. Fragments from the pumpings show this shale is slightly unctuous, gritless, and compactly impervious, resembling the red shale which has been penetrated in a number of deep wells in the state, and been found to have a great thickness; notably the well at Mankato in the Minnesota valley. While this shale, as shale, is impervious, it is interbedded with red sandstone, particularly in its upper portion, and from these beds of sandstone may rise an artesian flow of fresh water. At the time of my visit it had been entered but forty-six feet.

Mr. C. F. Sidener, of the university of Minnesota, analyzed this brine, and has reported the following composition of the soluble mineral ingredients:

	Grains per gallon.
Silica,	12.15
Aluminum oxide,	2.38
Carbonate of iron,	1.08
Calcium sulphate,	116.08
Calcium chloride,	156.55
Magnesium sulphate,	71.12
Magnesium carbonate,	78.60
Magnesium chloride,	91.44
Potassium chloride,	42.26
Sodium chloride,	2,764.99
Total mineral ingredients,	3,336.65

Of the mineral ingredients this gives 82.8 per cent. chloride of sodium, the rest being largely made up of the earthy chlorides of calcium and magnesium, and the sulphate of lime. This gives it more than the average per cent. of chloride of sodium found in the Michigan brines, while the total solid matter in solution is only from one-third to one-half as much.

There is an interesting question presented by these salt springs and deep wells of the Red river valley, viz.: From what formation does the brine issue primarily? Professor Hind inferred, from the great predominance of the salt springs over the rocks of the Devonian age, along the southwesterly side of lakes Winnipegosis and Manitoba, that the brine issues from the rocks of the Devonian. He rather discourages the expectation of Carboniferous strata in the region explored by him, saying that "it appears tolerably certain that the Carboniferous series is not represented in the only locality where it may be looked for with much chance of success." Sir Roderick Murchison, however, in his address before the Royal Geographical society, on the results of the "Palliser expedition," distinctly states that it is definitely settled that in the western portion of the Saskatchewan valley the Devonian rocks are overlain by Carboniferous strata. It seems reasonable to infer that these Carboniferous strata extend far enough southeasterly to occupy the unobserved interval of 400 feet of strata, stretched over a space of ten miles in breadth, "between the salt springs south of Dauphin lake, and the out-

* According to Prof. C. E. Bessey this plant is known on the salt marshes of Nebraska near Lincoln. (Letter Oct. 10, 1885.) —N. H. W.

crop of the Cretaceous shales on the flanks of Riding mountain."* The gypseous and salt-bearing formation of Michigan might occupy this interval. That the salt water issues from near the summit of the Devonian, if from the Devonian at all, is admitted by professor Hind. In order to issue thus along the summit of the Devonian outcrop, it must be confined in some superior basin. Professor Hind also brought home a specimen of *Productus*, which had been given him by a half-breed, who had extracted it from "solid rock;" but he is disposed to discredit the authenticity of this reported "solid rock," and to refer the fossil to some boulder transported from the south by floods and ice in the Red river, although Mr. Billings, who examined it, says that "there seems to be evidence of the existence of at least a portion of the Carboniferous system in this region." The salt-bearing beds of the Carboniferous in the State of Michigan have since been brought to light, and they yield that State a very important source of wealth. Had this fact been known by professor Hind, it seems to me he would not so summarily have dismissed the idea of Carboniferous salt-bearing strata, and all other Carboniferous strata so plainly indicated by the single specimen of *Productus*.

The horizon from which the brine issues at Humboldt appears to be in the Cambrian. It seems to pervade several geological horizons, from the summit of the Devonian downward to the Potsdam –but only superficially, the original source being higher than the Devonian. It is confined by the overlying sheet of impervious clay of which the drift mainly consists in the Red River valley, and is held under hydrostatic pressure by the downward pressing fresh waters that enter the same pervious gravel-and-sand stratum at higher levels toward the east, south, and west. Where the salt springs occur it finds escape to the surface through openings in the clay-sheet. These springs seem to be most frequent and copious in Manitoba, along a belt of country running east and west, where, for some reason, the drift-sheet is much less thick than it is further south. That brine, so pure and so strong, should be found at so great a distance, both stratigraphically and geographically, from its source, indicates the purity and strength of the brine in its native strata.

It remains for the future to determine whether these salt deposits shall become economically of importance to the Northwest. It is certainly the dictate of wisdom to give them a thorough examination and a fair trial. If these brines originate in Carboniferous strata that strike through the base of Riding mountain, they can easily be discovered in their native place. If those strata exist in that locality the strongest brine would naturally be found by sinking wells into them at some point further toward the south and southwest.

A sample of salt made from this well was exhibited at the New Orleans Industrial and Cotton Centennial exposition, this being the first ever made from brine native to the State of Minnesota. It was furnished by Mr. Valentine.

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*Reports of Progress, together with a preliminary and general report on the Assiniboine and Saskatchewan exploring expedition. Original edition, quarto, p. 175.—Henry Youle Hind.

SURVEY OF MINNESOTA.
BELTRAMI COUNTY
BY J.E.TODD.
Explanation
Glacial
Modified drift, gravel, sand or alluvium
Till, flat or undulating often marshy
Morainic, with rough topography
Archean
Slate
Granite and mica schist (or gneiss) with diabases
Kames
Beaches
Roads
Railroads
Contour Lines are shown approximately, for every 50 feet above the sea
Fifty foot contours
Hundred foot contours
Note. Below the highest beach line the till is more or less covered by lacustrine deposits.
NORMAN CO.
POLK COUNT
BECKER CO.
CASS COUNTY
ITASCA
T. 143 N.
T. 144 N.
T. 145 N.
T. 146 N.
T. 147 N.
T. 148 N.
T. 149 N.
T. 150 N.
T. 151 N.
T. 152 N.
R. XXXVIII W.
R. XXXVII W.
R. XXXVI W.
R. XXXV W.
R. XXXIV W.
R. XXXIII W.
R. XXXII W.
R. XXXI W.
R. XXX W.
Twelfth Standard Parallel
Thirteenth Standard Parallel
STATE PARK
Bemidji L.
Cass Lake
Red Lake Agency


MARSHALL CO
ROSEAU CO
Lake of the Woods
Cormorant Rock
Rocky Pt
Long Pt
Stony Pt
Oak Point
Fifteenth Standard Parallel
Fourteenth Standard Parallel
Muskeg
Winter Road
Swamp Cr
Rapid River
Red
Big Pt
Poplar Cr
T. 154 N.
T. 155 N.
T. 156 N.
T. 157 N.
T. 158 N.
T. 159 N.
T. 160 N.
COUNTY
INTERNATIONAL BOUNDARY
Lake of the Woods
Oak Point

CHAPTER VII.

THE GEOLOGY OF BELTRAMI COUNTY.

BY J. E. TODD.

Situation and area. This is the next to the largest county in the state (plate 64), is unorganized and lies mostly in the Red Lake Indian reservation. It was named after count Beltrami, who visited it in 1823. According to the estimates of the first volume of the final report, this county has an area of 6,007.12 square miles, of which 1,037.6 are water.

Its limit upon the north is the international boundary, which it should be remembered has a northern extension on the west side of Lake of the Woods, so as to include what is called the "northwest angle." On the east its boundary is the north and south line between the township ranges 29 and 30, which separates it from Itasca county. Its southern boundary is the Mississippi river, which separates it from Cass county and the line separating tiers 142 and 143, which separates it from Becker county, and its western boundary the line between ranges 38 and 39, which separates it from Norman, Polk, Marshall, and Roseau counties.

Our knowledge of the county is far from complete. It is derived from the reports of early travelers like Beltrami, who called attention to some of the peculiar geographical features of the region and published his results in French at New Orleans in 1824, some time before the official report of major Long's expedition with which he was for some time connected; from Schoolcraft and Nicollet; from the notes of lumbermen and land surveyors; the recent study of Mr. Upham, the report of which is subjoined; the survey of the Duluth and Winnipeg railway made in 1890; and also of the Fosston branch of the Great Northern; and the results of several trips made by the writer, viz.: From lake Itasca by Spain's to lake Bemidji, and thence to Red lake by way of Bagley's dam; also from the latter point to Fosston; from the northeast corner of the north Red lake around the east shore to the agency and thence along the trail followed by Beltrami down Turtle river to Cass lake and up the Mississippi to lake Bemidji; also a trip from Thief River falls to Rainy river, five miles above its mouth and at different times from Jadis along the south shore of Lake of the Woods to the Rainy river and up that stream to the mouth of the Bowstring or Big Fork river.

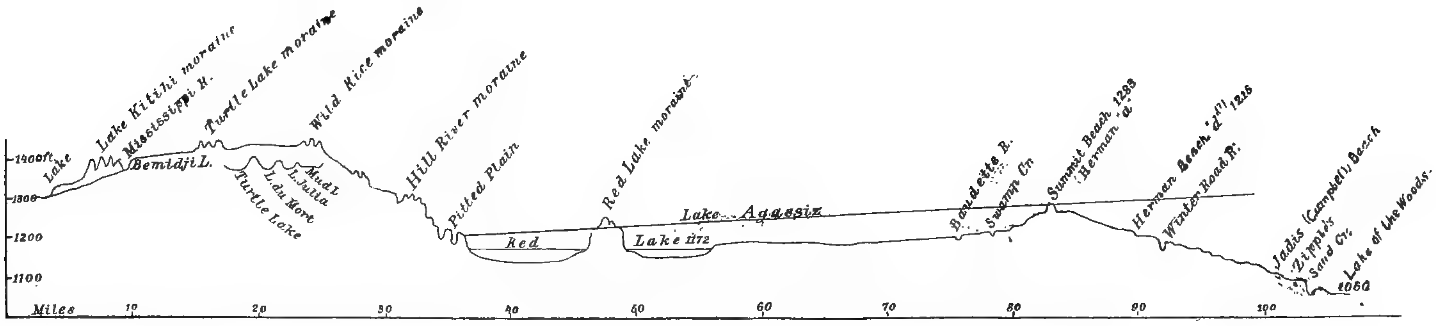
SURFACE FEATURES.

General topography. It may be divided into two quite distinct portions: one of them being quite even and level and formerly a portion of the bed of lake Agassiz; the other more elevated, much rougher, cut by streams and traversed by moraines. The line dividing these two portions crosses the county from east to west three to ten miles south of Red lake or approximately along the tier of townships 150. The highest part of the county is probably a little south of lake Itasca, where the altitude

is estimated to be over 1,750 feet. The altitude of the southern rougher region lies between that and 1,250, the approximate level of the highest beach of lake Agassiz.

Contrary to general report and representation on maps, instead of there being a ridge marking the watershed between the Mississippi and the basin of Red lake and Red river, the surface is nearly level and has an altitude of about 1,400 feet. The slope from this level to that of the region north is marked by two or three tolerably distinct terraces. The fuller discussion of this region will naturally be given when we speak of its moraines.

The northern and lower division, or the rest of the county, is largely occupied by swamps of different character, viz.: those covered with tamarack, cedar, spruce, moss, or grass. The elevation of this region slopes from 1,250 on the south to about 1,050 on the north. There is an exceptionally elevated area whose extent is not determined which in places rises to 1,250 to 1,300 feet. This occupies the region of perhaps 200 square miles about the headwaters of Roseau river south of the southwest portion of Lake of the Woods. From the fact that it was surrounded with beaches and probably was in part above the surface of lake Agassiz after the recession of the ice-sheet, it has been named by Mr. Upham, Beltrami island. The section is shown in figure 11.



Profile from N.W. corner of Tp. 145. 31 along the line A-B to Zipple's on Lake of the Woods

FIG. 11.

Drainage. The most extensive basin of the county is that draining into Red lake, the principal streams of which will be found described by Mr. Upham in his report subjoined. The basin occupies nearly one-third of the county. South of this is that of the Mississippi, whose main features have already been described in connection with Cass county, but a few notes upon its northern tributaries may be added.

The first tributary from the west is a small stream draining from two channel-like lakes in the southwest part of T. 144-36. These have not been visited, but from their position and shape are considered part of an old drainage channel connecting the Mississippi with the south branch of the Wild Rice river. The next is Moose creek, a small stream draining the south half of T. 145-36. The next tributary of the Mississippi enters from Manomin lake which occupies most of sec. 24, T. 146-35. It receives on its northern side two important streams (or rather, one formed by the junction of two, shortly before entering the lake); one from the west, the Little Mississippi or Piniddiwin. This has two branches, one rising in the northern part in T. 147-36 and the other in the northwest corner of the township immediately south. Both these tributaries are connected by swamps with short branches of the Clearwater, the main stream being not more than four miles distant. In T. 146-25,

FIG. 1. VIEW OF THE NORTH END OF TURTLE LAKE, LOOKING SOUTH. HEAD OF THE MISSISSIPPI ACCORDING TO BELTRAMI. (p. 133.)

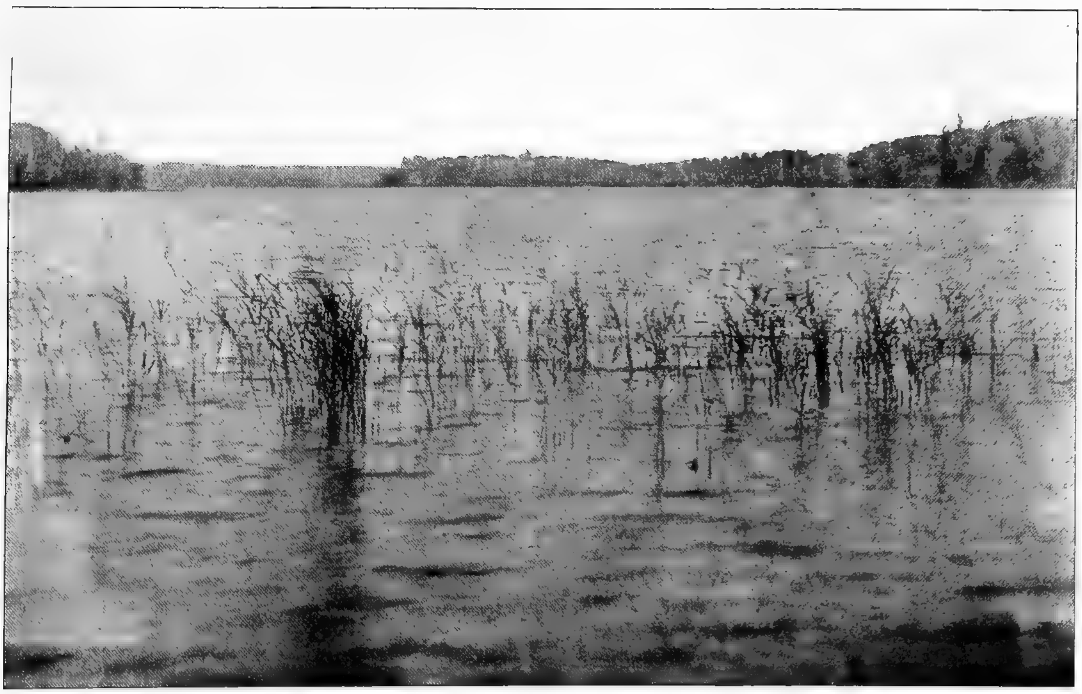


FIG. 2. LAKE JULIA, FROM NEAR THE SOUTH END, LOOKING NORTH 20° WEST. (p. 133.)

FIG. 1. TURTLE CREEK, ENTERING TURTLE LAKE, LOOKING NORTH 80° EAST, TOWARD THE OUTLET OF THE LAKE. (p. 133.)

FIG. 2. TROUGH AND TERRACES OF MILL CREEK AT RED LAKE AGENCY, LOOKING SOUTH OF WEST. (p. 156.)

this is about three feet wide with a valley fifty to seventy-five feet below the upland. The other tributary, Grant creek, approaches Manomin lake from the northeast. It rises in sec. 4, T. 147-35, within three miles of the Clearwater, flows southeast to the middle of the south line of T. 137-34, then turns southwest to its junction with the Little Mississippi just before it enters the lake. This stream has quite a shallow trough not more than ten or fifteen feet below the general level. From this point the Mississippi receives another tributary from the north before it reaches Cass lake.

At the north end of that lake the waters of the Turtle river enter. This is an important stream which has a remarkable course and was counted by count Beltrami as the main branch or source of the Mississippi. Its extreme head is in the southwest corner of T. 149-34, closely connecting with the head of Sandy river, which flows northwest into Red lake. From this starting point Turtle river flows east-northeast to the west side of West Turtle lake, or Lac du Mort, which occupies the most of sec. 17, T. 148-33. In making this course it traverses three lakes, each one more than a mile in length, and the east one of these, in the middle of the east side of T. 148-34, connects with a chain of lakes coming from the west-southwest. At the north end of West Turtle lake (figure 1, plate L) there was formerly a trading-post which was on the line of travel from Cass lake to Red lake, and it was along this trail that Beltrami came. The north end of this lake is connected by the channel-like valley with the head of Mud river, or, as it is sometimes called, Red Lake river, as Beltrami considered this stream the most important tributary of the Red Lake river, and therefore the head-water of the Red Lake river. In this channel lies lake Julia, so named by Beltrami after a lady friend of his. (Figure 2, plate L.) The north end of the lake, and the channel before mentioned, are depressions sixty or seventy-five feet below the average level of the country surrounding.* The Turtle river enters this lake, as is shown in figure 1, plate M, on the west side, near the south end, and leaves it directly east in the northeasterly direction, and shortly enters East Turtle lake, which is about five miles in length and one mile and a half in breadth in the broader portion. The length of the lake is north and south. The stream leaves it near its southern end toward the northeast, and after traversing for a few rods the west end of Gnat lake, which is about two miles in length, and from the east end of which is a portage one mile and a half to Turtle River lake, it passes north and traverses the lake north of Gnat lake, about two miles in length, turns east, then southeast and enters the west end of Turtle River lake near the before mentioned portage. This portion of its course is narrow, stony and much broken with rapids. Turtle River lake is about four miles in length, of irregular form, connected with elongated bays, lies mostly in the northeast corner of T. 147-32. From the east end of this lake the river takes a northeast course to a small lake in the northeast corner of sec. 25, T. 147-31, thence by a southward course of two miles enters Ketihi lake, and then by a narrow lake-like channel, about a mile in length, it reaches the middle of the north side of Cass lake. This stream receives several quite important tributaries from the north. One enters the north side of Turtle River lake in the northeast corner of sec. 3, T. 147-32. This drains the swamps and lakes to the north, its head being in section 17 of the township north. Another tributary joins the river in sec. 32, T. 148-31, which rises in a lake in the northwest corner of the same township. The largest tributary rises near the centre of T. 149-30, and after a very crooked course it traverses a crooked lake about three miles in length in the west half of the township south, turns west nearly to the centre of the next township west, then southeast and south to the northwest end of Pimush lake. This lake is about six miles in length, narrow and somewhat crooked. The river leaves it in the northeast corner of T. 147-31, and joins the Turtle river in the west half of section 23 of the same township. These lakes are attended with extensive swamps, and the country surrounding is generally low, except where traversed by moraines which are located in a subsequent section.

The extreme southwest township of the county drains into Otter Tail river, which is the head of the Red river of the North. This rises in section 4 of the township and flows south, leaves it in section 31. The T. 143-37 with small portions of the adjoining townships, does not drain into any stream. Another small portion north of the last mentioned lies in the basin of Wild Rice river. This rises in Upper Rice lake, which is a round lake about one mile and a half in diameter and mostly in the northwest corner of T. 145-36. The stream flows southwest to Lower Rice lake, receiving the tributary from the southeast near the centre of T. 145-37. Lower Rice lake is about three miles in length, extending north and south from secs. 15 and 35, T. 145-38. Both these lakes gain their names from the abundance of wild rice which grows in their shallow waters. Another tributary some six miles in length enters from the main stream, runs west-northwest and leaves the county in the northwest corner of the township

The Clearwater is an important stream which rises in the northwest corner of T. 146-36, turns north for a couple of miles, then due east about seven miles, east-northeast fifteen miles, which brings it to Bagley dam in the southeast corner of T. 148-35, turns with a sharp bend, and flows nearly due north about eight miles to Clearwater lake, which is about three miles in length. From that point it flows northwest in quite direct course to the northwest corner of T. 151-38, where it leaves the county. Its valley above Bagley dam is quite shallow, but

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*Dr. Norwood gives the following description of the portion of the trail as it crosses the watershed. See Owen's report, 1852, p. 325.

"The portage from Lac des Morts is eleven hundred and forty paces long and leads to Hill lake (lake Julia), the waters of which flow into Red lake. The highest point of the portage path was estimated to be fifty-two feet above the level of Lac des Morts, and the highest ground, seen on the east of the portage, was not over twenty feet higher. To the left of the portage is a small pond connecting with Lac des Morts, and between this and Hill lake is a low swamp, through which the waters flowing north and south of the dividing ridge must connect in times of high water. The dividing ridge is timbered with oak, ash, aspen, birch, soft maple, bass-wood, and elm."

After going over the same ground I endorse the statements, with the single exception that the highest point in the connecting channel is twelve or fifteen feet at least above lake Julia and the beautiful circular pond, which for convenience I have called Gem lake. According to the barometer there are points eighty to ninety feet above the lakes a few miles east.

at that point it has reached the depth of forty feet or more and from there to Clearwater lake runs in a narrow gorge with rapid descent from 50 to 125 feet in depth. Its course below Clearwater lake has quite high banks until it passes from the hill country to the swamps in the southern portion of T. 150–37. From that point it makes its way with low banks through swampy ground. About the midddle of T. 150–37 it receives a tributary from the south which rises in the southern portion of T. 148-37.

Lost river rises in the southern part of sec. 34, T. 150–38, flows northwest to the northwest corner of the township, then gradually turns to the northeast, traverses a broad ridge about two miles in length, continues with the same course to sec. 3, T. 149–38. It receives another branch about twelve miles in length in the west half of T. 148-37, then turns northwest, into the N. W. ¼ of T. 150–37, where it loses its identity in a broad marsh. From this fact it gains its name.

Rainy river and its tributaries. Rainy river is the largest river connected with Minnesota. It touches this county in the northwest corner and describes a quite regular curve from that point to where it enters the Lake of the Woods. It is a deep, rapid stream with an average width of about one-fourth of a mile. Its banks are rarely over twenty feet in hight, and covered on either side by alluvial land thickly covered with deciduous timber, consisting of elm, oak, poplar, and cottonwood, with occasionally groves of white and red pines. From the south it receives numerous tributaries, which usually appear wide and sluggish and often give a wrong impression of their real importance. Some of them may be less than two miles in length, while others no greater at the mouth may be twenty times as long.

The first stream of importance which enters Rainy river from this county is Rapid river. It was named probably from the picturesque fall or rapid just above its mouth. At this point the river makes a plunge of twenty to twenty-five feet over a ledge of black siliceous slate; above this point it is sluggish and there may be places more than twenty or twenty-five feet in width. It is said to receive a tributary of some size from the east a little way above the falls. It rises in the swamp north of Red lake and is crossed by the "Winter Road" trail ten or twelve miles north of the mouth of the Two rivers which flow into that lake. At that point it is said to be twenty-five or thirty feet in width. The survey of the Duluth and Winnipeg railroad, which runs direct from the northeast corner of Red lake to the southwest corner of Lake of the Woods, crosses the stream about twenty miles from the former lake. Its channel has a depth of about twelve feet below the marsh on either side. Its course is quite direct northeast. The next river is Baudet to Pine river. This is crossed by the before mentioned survey about six miles from Rapid river and appears to flow nearly parallel with it. Its source probably lies about twelve or fifteen miles west of that point where water in the swamp was found by us gradually flowing to the east. A little east of the railroad crossing it receives a branch from the northwest known as Swamp creek, which rises probably in the large muskeg and lake about twelve miles a little north of west. It is not certain that such is the fact. A muskeg extending about five or six miles northwest and southeast was found in the locality indicated, and north of it a small open lake surrounded by timbered banks but few feet in hight which was named O'Brien lake. From conversation with hunters the opinion was expressed by some that this lake was at the head of the main branch of the Roseau river and we crossed east of its mouth, noting an outlet or movement of the water in the swamp. However, as the land to the north is generally high and a pine ridge is north and west of it, it seems altogether reasonable to suppose that Swamp creek drains this ridge and swamp. This river is also called by the Indians Big river. It enters Rainy river about thirteen miles above its mouth.

Between the mouth of this stream and that of the Winter Road river we noted three or four narrow inlets or streams coming from the south. According to reports of the Indians the Winter Road river flows nearly parallel with the Baudet. This receives a branch from the west about six miles above its mouth, which was crossed in our course to Rainy river ten or twelve miles before striking that stream. This stream gains its name from the fact that it is the starting point for the winter trail from the Rainy river to Red lake. Because there is a saw mill opposite its mouth, it is sometimes called Saw Mill river. West of this are two or three small streams, the first of which is called Pepper river or McCauley river. One five or six miles in length entering Rainy river about five miles above its mouth we have named Hovland creek. Rainy river, as will be seen from the map, enters a narrow bay separated from the main lake by a narrow peninsula and narrow island into the headwaters of this bay. This bay is called Four Mile bay. Into this bay comes a small stream called Four Mile Bay creek, which rises on higher ground several miles south. At Zipple's fishery on the south shore of Lake of the Woods a creek of considerable size known as Sand creek enters the lake. It rises fifteen or twenty miles southwest and where crossed by the railroad survey is about 130 feet above the lake and has a valley about six feet in depth.

War Road river enters the southwest extremity of Lake of the Woods. It rises in the northern part of the highland region. To the south it probably has a length of twelve miles. Where it enters the lake it is a sluggish stream forty to fifty feet wide with swampy banks in places.

The western side of the region known as Beltrami island is drained by three or four branches of the Roseau river. Their sources have not been determined. The longest branch probably rises near the head of Baudet river, on or near T. 157-36, where we found water moving in a swamp toward the northwest. Information was furnished by hunters who had visited that region to the effect that this branch of the Roseau started from a small lake connected with the large swamp.

Besides these streams it should be remembered that a small area of the country is drained by the headwaters of the Moose river and the Mud river into the Thief river.

That portion of Lake of the Woods lying within our territory comprises the main part of the more open portion called sometimes Sand Hill lake after the dunes which mark the mouth of Rainy river. As Dr. Lawson well remarks: "The northern portion has an excessively irregular, rocky coastline, and its whole expanse is thickly

studded with islands, varying in size from mere rocky islets to masses of land many miles in extent. "The southern portion presents the contrasting character of a broad sheet of shallow water, almost totally free from islands, contained by low, sandy or marshy shores of gently sinuous outline, in which rock exposures are extremely few, the whole in remarkable opposition to the jagged cliffs and tortuous island-blocked channels of the northern portion.

"The line of demarkation between these two naturally distinct portions of the lake is nearly coincident with the international boundary line from the 'northwest angle' to the mouth of Rainy river, were that line to bend round so as to pass the southern extremity of Bigsby island and strike the main shore south of Little Grassy river, it would separate as nearly as possible the two portions of the lake thus characterized.

"The northern portion of the lake occupies a short, broad belt of green schistose Archean rocks which have hitherto been referred to the Huronian. The southern portion appears to be wholly in a basin of Laurentian gneiss, the flanks of which pass beneath the drift on the Minnesota shores to the south and west."

Mr. Wm. Zipple, who has had many years' experience in the fisheries, informed me that the lake was about thirty-five feet deep in the widest portion, but 150 feet toward Rat Portage.

It may not be out of place to supplement Mr. Upham's notes on the Red lake streams with a few additional facts. The largest stream flowing into Red lake is that known as Black Duck, which enters South lake near its eastern end. Mr. J. C. O'Brien informs me that in the freezing of the lake the water remains open longest from the mouth of this stream to the outlet of Red Lake river, which would seem to indicate the bed deepest along that line. This stream drains a fertile region. It rises in Black Duck lake, which occupies about five square miles in the northern part of T. 149-31. It is spoken of as a beautiful lake with high banks, especially on the southern side. Southwest of it four or five miles is another lake called Gull lake.

The source of the Mississippi. It has been the occasion of considerable recent discussion to determine the true source of this river. It is more a question of geographical definition and individual curiosity than of practical importance. The survey of Hon. J. V. Brower, under the auspices of the Minnesota Historical Society (published as vol. vii of the collections of that society), satisfactorily closed the discussion, reaching the conclusion that, while Itasca lake may be accepted as the source of the Mississippi, there are several other small streams which flow into that lake, and if the highest source be sought, above Itasca lake, that honor would fall to Nicollet creek, which rises several miles south of Itasca lake.

This controversy has more recently been reviewed by Prof. E. Levasseur in vol. viii, Minnesota Historical Collections, with the same result, and finally, after a republication by Glazier of his claims in favor of Excelsior creek and Elk lake, a critical summary history and examination have been given by Prof. Winchell (Minn. Hist. Coll. viii, 226, 1896), who concludes as follows:

"The question may be relieved of all side issues and narrowed down to two propositions: 1. Which is the larger and longer valley? 2. Who discovered these valleys and water courses?"

It is a singular fact, as appears from the representations of Glazier, that Elk lake was not seen either by Schoolcraft or by Nicollet, although they were both in pursuit of the source of the Mississippi under the guidance of the Indians, a fact which indicates the estimate put by the Indians on the relative importance of these streams. The actual measurement of these streams has been made at their mouths by several persons. The Nicollet stream, which is the continuation of the main valley of Itasca lake to the southwest, according to Glazier has a width of ten feet and a depth of two and a half feet. The Elk Lake stream has a width, by the same authority, of seven feet and a depth of three feet. The channels are, therefore, in point of capacity, as the numbers 25 to 21. If the velocity of the streams be considered the same, the Nicollet creek would carry nearly 20 per cent. more water than the Elk Lake stream. But, according to the descriptions, the Nicollet creek is more rapid than the Elk Lake creek, and may be estimated to carry twice as much water as the Elk Lake stream.

In point of view of the length of the two valleys, or more correctly, of the two streams, Nicollet and Brower trace Nicollet creek to a distance of several miles above Itasca lake, but Glazier allows this stream only a length of a mile and three-eighths. The valley which is drained by Excelsior creek, the chief tributary of Elk lake, Mr. Glazier followed a distance of 14,106 feet beyond Itasca lake. From these data he decides that the length of "running water" is much greater in the Elk Lake valley. There are, however, several facts bearing on the length of Nicollet creek which Mr. Glazier does not mention. He traces it up to a great spring. He is willing to suppose that a stream whose depth is two and a half feet, with a width of ten feet, may have its gathering area all embraced within a mile and three-eighths of its debouchure. Had an explorer, intent on finding the source of a stream, found it issuing apparently from the ground with such a volume, his own judgment would have driven him to search further up the valley, as did Nicollet, Clarke, and Brower. He would there have found the same stream reappearing and again disappearing, sometimes in lakes or in marshes, lost to sight as running water, like a "bashful maiden," as described by Nicollet, finally plunging mid a screen

of vegetable debris, bogs, peat, and floating drift wood, much overgrown with small trees, only to come to the light of day again at the "great spring," 7,307 feet from lake Itasca.

The length of this water course, thus included, is considerably more than the farthest traceable limit of Excelsior creek. It may not be in lake Hernando de Soto, as supposed by Brower, that the highest actual water of Nicollet creek can be identified, but it is certainly several thousand feet above the point adopted by Mr. Glazier. In northern Minnesota, where vegetation is rank, and the materials in which it grows are loose, like the sandy subsoils about Itasca lake, it is no uncommon occurrence to find small streams blocked by such obstructions. They spread out, disappear in marshes, plunge under floating bogs, or driftwood, and issue at lower levels. The St. Louis river, the principal stream entering at the head of lake Superior, was permanently invisible for the distance of nearly a mile, near Cloquet, until within a few years. It flowed under a mass of floating driftwood on which grew small birches and aspens. Lumbermen finally cut the driftwood away for the purpose of floating logs to lower points. The celebrated raft of the Red river, in Arkansas, is a parallel case. The principle is the same as with the obstructions to Nicollet creek. Such interruptions of "running water" are not limitations of the valleys nor of the streams that drain them. They are non-essential accidents, and can not be considered as having any important bearing on the true size and length of Nicollet creek.

This important omission of an essential fact in the investigation conducted by Glazier seems to be fatal to the claims of Elk lake and Excelsior creek.

We next ask: who discovered Elk lake, which has now been named "Glazier lake" by the recent travelers? It was thought at one time that Julius Chambers entered it in 1872, but Mr. Glazier shows that his description applies rather to one of the lakes of the Nicollet valley. Mr. Glazier found it in 1881. He hastily promulgated it as a new discovery, announcing this at various points on his way to the mouth of the Mississippi. In 1875, however, this region had been surveyed by the officers of the United States land survey under Gen. James H. Baker. This lake was platted and reported in the regular manner, to the government at Washington, under the name which it seems to have borne among the Indians and early explorers, *Elk lake*. As such it has gone into the official records. The Minnesota Historical Society has approved this nomenclature, and finally the Minnesota Legislature has passed a law declaring that in the public schools of the state no geography shall be used by the pupils which gives this lake any other name. The fact of the earlier naming of this lake is not disputed by Glazier. He claims priority on the ground that the business of the land surveyors was not to discover the source of the Mississippi, that they did not trace out its feeders and that they did not make wide publication of their discovery. If these be considered fatal defects in the governmental discovery of this lake, it is probable that there will be no objection to admitting the priority of Glazier.

When a careful and dispassionate examination is made of the essential facts, as now known, the conclusion is forced that Mr. Glazier fails to substantiate his claim. A hasty examination of his last work, without a full knowledge of the facts brought out by the Minnesota Historical Society's survey, would lead to the favorable consideration of his claim, since he evades the adverse facts, and dwells on the repeated assertions of his friends and followers, and on the favorable showing which he is able to make in respect to the lake which he found in 1881. History and geography cannot be promoted by such partial and interested advocacy.

If Itasca be not allowed to stand as the source of the Mississippi, the competition lies between Nicollet and Excelsior creeks, and the former has the greater length and volume. If it is necessary to choose another lake as its source, then some of the upper lakes of the Nicollet valley must be accepted. If finally it be necessary to accept Elk lake, that lake was first discovered and mapped by the United States surveyors in 1875. Mr. Glazier's claims, in every respect and in any case, are thus annulled, on the basis of facts which if he does not himself publish he does not call in question.

Figures 2, plate J, and 1, plate K, show the relative size of these two streams, and figure 2, plate K, gives a view of Elk lake.

ELEVATIONS.

The following tables of elevations are mostly railroad levels. A few are barometric and such are indicated. The survey of the Great Northern railway from Fosston to Leech lake is taken from Bulletin 72, U. S. Geol. Survey.

Great Northern railway—Fosston to Leech lake.

	Miles from Carman.	Feet above the sea.
Summit, near the east line of sec. 35, T. 147-39,	53.5	1,545
Lakes, three-fourths mile east and southeast from the last,	54.2	1,485
Head stream of Clearwater river, bed, mud to depth of ten feet,	56.1	1,439
Creek tributary to Wild Rice lake, bed, 1,466; bottom land, 1,469,	61.8	1,466
Mississippi on sec. 8, T. 145-35 (about thirty feet wide), bed, 1,371; water, 1,373, bottom land twenty-five or thirty rods wide, 1,376; proposed grade,	77.1	1,409
Leech lake water, raised by dam,	121.2	1,297

Duluth & Winnipeg railroad.

From profiles of the chief engineer noted and furnished by Mr. Warren Upham. The following is an abridgement of the notes as furnished:

	Miles from Duluth.	Feet above the sea.
Outlet of Cut Foot Sioux lake, water, level with lake Winnibigoshish, 1,292; grade,	125.4	1,299
Summit, cutting nine feet; grade,	128.0	1,314

FIG. 1. VIEW NORTH 20° EAST, AT THE MOUTH OF NICOLLET CREEK. (p. 136.)

FIG. 2. ELK LAKE, FROM MORRISON HILL, LOOKING SOUTH 20° EAST. (p. 136.)

	Miles from Duluth.	Feet above the sea.
Pigeon river, bed, 1,301; grade (not at bridge),	130.0	1,310
Pigeon river, bed, 1,306; water, 1,308; grade,	130.9	1,313
Summit, natural surface and grade,	134.4	1,350
Summit, cutting nearly twenty feet; grade,	150.7	1,442
Shotley creek, first crossing, bed, 1,303; water, 1,304; grade,	162.4	1,324
Shotley creek, third crossing, bed, 1,300; water, 1,301; grade,	162.7	1,318
Tamarack river, bed (sand) 1,165; water level with Red lake, 1,172; grade,	175.5	1,179
From the distance of 178 miles (grade, 1,179) forward along the next eighteen miles to the Moose river is a continuous swamp, "tamarack and spruce swamp," its northeastern border being the northeast shore of the northern part of Red lake. The depth of the swamp mud ranges from five to fifteen feet, being mostly from seven to ten feet. In many places the hard bottom is noted as gravel and sand. The proposed railroad grade is 1.5 to 2.5 feet above the swamp surface.		
Summit in this swamp, grade,	184.7	1,195
Moose river, bottom of mud here six feet lower than bottom of mud 100 feet distant on each side, 1,162; water, 1,164; grade,	196.7	1,172
Rapid river, bed 1,155; top of banks and land on each side, 1,161 to 1,163; grade,	197.6	1,167
Hard ground extends between Moose and Rapid rivers, and to 198.1 miles, succeeded by spruce and tamarack swamp, thence to 202.7 miles, with mud six to nine feet deep, the grade line being 1.5 to 2.5 feet above the swamp.		
Summit, hard bottom, 1,166 to 1,168; swamp surface, 1,175; grade,	200.7	1,177
Baudette river, bed, 1,158; water, 1,160; grade,	203.1	1,170
Swamp creek, bed, 1,175; grade,	205.2	1,181
"Tamarack, spruce and cedar swamp," reaches from 204.6 to 208.8 miles, excepting a beach ridge of lake Agassiz at 206.9 miles, with crest at 1,219 feet, being five feet above the swamp on the southeast side, and one foot above it on the northwest side.		
Northwest limit of this swamp, surface,	208.8	1,250
Sand and gravel knolls, 10 to 15 feet above the depressions, crests at	209.4–210.1	1,270–1,283
A smooth surface of gravel and sand extends thence to summit, natural surface and grade,	211.8	1,283
Smooth and slightly undulating sand and gravel reaches onward to edge of swamp (1,234 feet) at 217.2 miles; and thence the swamp, with mud 5 to 12 feet deep, to gravel and sand bottom, reaches to 222.8 miles, there having an altitude of 1,224 feet.		
Summit, cutting 5 feet, probably in sand; grade,	223	1,231
Eroded shore line of lake Agassiz, crest of escarpment, 1,224; base of the same, nearly at the former highest (1) level of lake, 1,215; distance, 224.1 miles.		
Winter Road river, bed, 1,194; banks, 1,198 to 1,200; grade,	224.8	1,205
Summit, cutting, 3 feet; grade,	225.5	1,207
Bear creek, bed, 1,189; grade,	226.5	1,196
Sand creek, bed, 1,172; grade,	227.2	1,186
A slightly undulating surface of gravel and sand, with frequent small and shallow swamps (mud 5 or rarely 10 feet deep), extends from Bear creek onward to 237.5 miles, where grade is 1,080 feet.		
In this distance of 11 miles the following beaches, representing ten stages (2–11) of lake Agassiz, are crossed, having altitudes of crests as noted: At 226.9 miles, crest (2), 1,196; at 229.6 (3), 1,172; at 230.3 (3a), 1,169; at 230.5 (3b), 1,168; at 231.3 (4), 1,156; at 233 (5), 1,143; at 233.6 (6), 1,127; at 233.8 (6a), 1,124; at 234.6 (7), 1,116; at 235.2 (8), 1,106; at 235.7 (9), 1,099; at 236.5–236.7 (10), 1,094–1,093; at 237.2 (11), 1,087.		
Beyond the last a smooth surface of sand, with no beaches, extends to War Road river, bed (of gravel), 1,036; bed (of mud at bottom of water), 1,045; water level with Lake of the Woods, 1,057; grade even with the general surface on each side,	239.8	1,070
Swamp, 3 to 6 feet of mud, with clay bed; surface of swamp,	240.0–240.9	1,070 1,074
Moderately undulating sand extends thence to end of this profile; grade,	241.7	1,079
This is about 9 miles short of the international boundary (250 miles) in the northwest course of the survey. The line of survey is very nearly a straight line from the shore of Red lake to the most southwest point of the shore of the Lake of the Woods.		

Commissioner Brower gives the altitude of the following points among others:

	Feet.
Itasca lake,	1,457
Elk lake,	1,458
Nicollet's Middle lake,	1,461
Nicollet's springs,	1,476
Nicollet's Upper lake,	1,496
Whipple lake,	1,551
Summit of the "Hauteur de Terre,"	1,750

The elevations along the line of Mary creek, which enters the east arm of Itasca lake, and which may be considered by some as a rival of Nicollet and Excelsior creeks, are:

	Feet.
Mary lake,	1,488
Danger lake,	1.513

GEOLOGIC FEATURES.

In this county we have the usual glacial drift and lacustrine deposits, besides important exposures of the underlying rocks.

The older formations. These belong, as far as we have examined, to the Eozoic time, and since the exposures are not extensive, we will simply enumerate the localities with brief notes on the macroscopic characters of the rocks. They are none of them more recent than the Huronian.

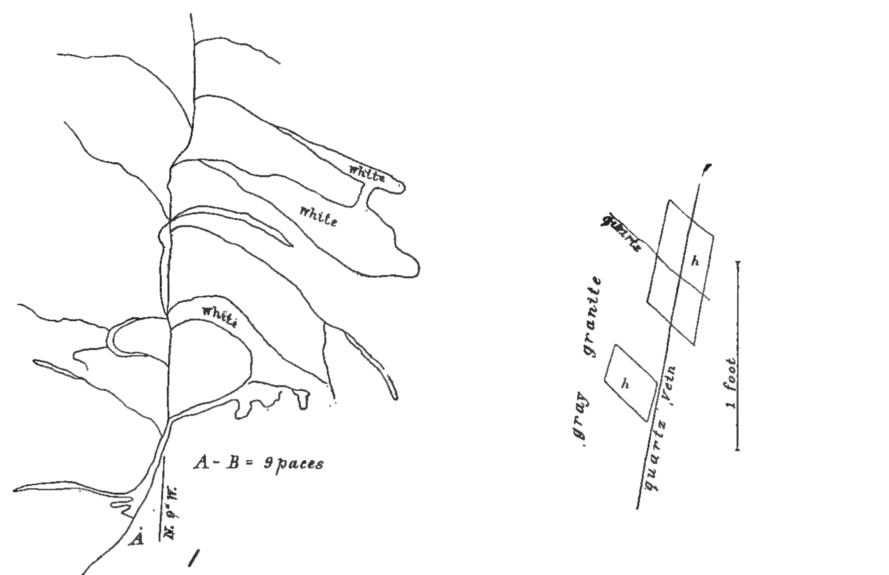
The northwest angle. Although we have not visited the "northwest angle," we make use of valuable information furnished by the report of Mr. G. M. Dawson, on the "Geology and Resources of the Region in the Vicinity in the Forty-ninth Parallel," 1875, also by Dr. R. Bell in his report of the country between lake Superior and lake Winnipeg, Geological Survey of Canada, 1872–73. Of these we have access only to short abstracts, given by Dr. A. C. Lawson in his report on the geology of Lake of the Woods region, 1885, and by professor C. R. Van Hise's correlation paper on the "Archean and Algonkian," 1892, Bulletin No. 86, U. S. Geol. Survey. From these we learn that the bed rock is largely granite, assuming "a more basic character and a darker aspect, becoming blackish, gneissic dioryte and gray syenitic dioryte." The whole area is probably composed of these rocks, thinly overlain by glacial and lacustrine deposits.

Buffalo point is probably also tipped with crystalline rocks. This is easily inferred from its resemblance in form to the neighboring rocky points, because it lies in line with the junction of the granite and gabbro exposed on Rocky point, mentioned in a succeeding paragraph.

Cormorant island. This is a bare rock rising about fifteen feet above the level of the lake, nearly due north of Rocky point, and nearly due west of Long point. It is composed of dark "gabbro," probably the same called syenitic dioryte above, abounding in magnetic grains. These were so numerous that no reliance could be placed on the compass. The needle swung all around the circle in going a few feet, even if held three or four feet above the surface of the rock. A hand specimen of it would hold a magnetic needle placed by it in any position. This rock is in places

coarse grained and porphyritic. It exhibits a striped appearance of wavy lines of light and dark shading into one another, giving a strong impression of lines of flowage.

Rocky point. This is a convex curve in the shore about two miles south of Cormorant rock. Much of the point is formed of rock rising ten or twelve feet above the lake, and bosses of rock, rounded by glacial action, are found along the shore, and rising like whalebacks in the water, a mile or more to the southwest and still further toward the east. Right at the point is the line of junction between pink granite upon the southwest, with the before mentioned dark gabbro on the northeast. This line is sharply defined and nearly straight. It was traced for about forty yards, then after being hidden for about the same distance, it was traced twenty yards further. Its direction is in line with the north side of Buffalo point, or about north 50° west. This junction apparently is vertical, and is like the side of a dike. Next the granite are a few inches of fine-grained greenstone, then a layer of white quartz, then another of similar greenstone, shading into the dioryte or gabbro. This gabbro is coarse-grained and porphyritic.



General plan of granite vein West of Zipples

2 Fragments of hornblendic schist in gray granite Zipples

FIG. 12.

Long point. This is a narrow ridge running many rods nearly straight north from the most prominent angle of the south shore of the Lake of the Woods. It is composed mostly of gray gneiss which shows patches and veins of a more hornblendic rock. No trace was found of the darker gabbro of Rocky point, and no disturbance of the needle was noticed. The dip was about 60° north 41° east.* The ridge rises from fifteen to twenty feet above the lake, and shows distinct traces of ice action.

*We assume in getting this, a variation of 11° east for the magnetic needle.

Stony point. This is situated about two miles southeast of Long point and consists of granite similar to that already mentioned. The veins of darker rock in it run between due north and magnetic north. The rock is said to rise in a knob about fifty feet in hight above the surrounding country only one-fourth of a mile from the shore. We were unable to find it on account of thick woods and inopportune rain. Several rocky islets appear in the lake about these points.

Another exposure was found at Zipple's fishery at the mouth of Sand creek. The one right at the fishery, little east of the mouth, is mainly of the dark magnetic gabbro before mentioned. It shows alternation of layers or veins often in lenticular form of white quartz, often with dark gabbro which varies much in fineness of texture. A sketch exhibiting these relations is shown in figure 13.

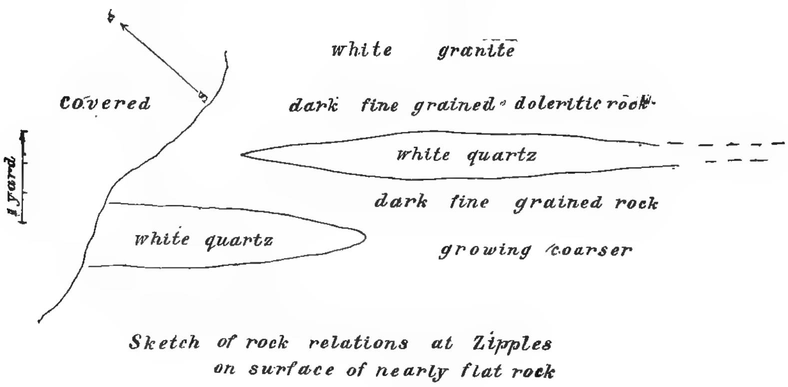


FIG. 13.

About one-half mile west of the fishery on the south side of Sand creek is a rocky knob covering perhaps five acres and rising about forty feet above the lake. The knob is composed almost entirely of gabbro, though no magnetic disturbance was noticed. It was very much veined with quartz and light colored granite. Peculiar contorted and arborescent forms of these are illustrated in an adjoining figure (12-1). On the lighter portion of the rock there were noted also a number of points rounded and angular masses of finer grained black rock, strongly suggesting fragments floating in a molten magma. One of these is shown in figure 12-2. Like others we have noted, these rocks show in their contours the shaping influence of glacier ice, though striæ were found only in one very limited area. From this point we found no exposures of crystalline rock along Rainy river until we reached the mouth of Rapid river. There, as we have before stated, is a high ridge of black schist or siliceous slate standing nearly vertical. It rises about thirty feet above Rainy river and the fall is about twenty feet. A rough sketch of the locality with its exposures is shown in figure 14. The strike of the older stratification, as it appears from colors and from the fineness of the grain in the rock, is about north 21° west. The chief joints are north 69° west. The lamination is north 73° east. Another cleavage is in the

direction of the strike, north 32° west. The dip of the main joints and of the cleavage is at a high angle. White quartz veins are found traversing this ridge northwest and southeast in an irregular manner. The rock is hard, fine grained, and very easily separable into laminæ. It resembles the small, black slate boulders that are found distributed over central Minnesota far south. No magnetic disturbance was noted at this point.

About one-half mile east of Rapid river an outcrop of dark gabbro, resembling that at Zipple's both in appearance and the effect upon the needle, was found at the level of the mouth of the river. The rock here shows no distinct veins, is quite uniform, and of fine grains. Dr. Lawson marks a dike at this locality on his map.

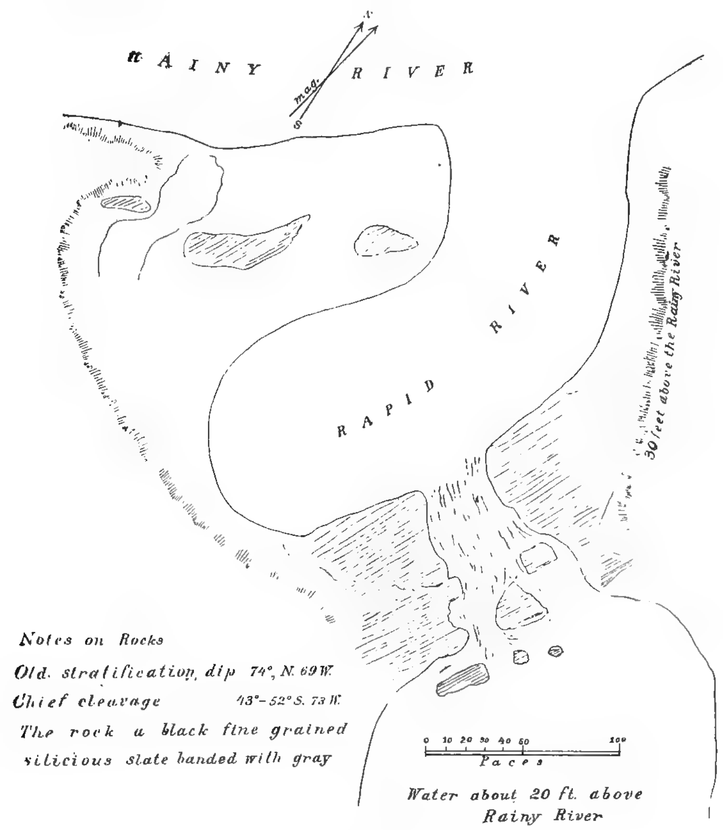


FIG. 14. MOUTH OF RAPID RIVER.

Paleozoic rocks. No clear outcrop of sedimentary rocks of this age has been found, but the abundance of white limestone and pebbles at some points strongly suggests that they probably exist not far below the surface. On Turtle river, just below Turtle River lake, where the stream is passing through a moraine by a succession of rapids, in the S. W. ¼ of T. 148–32, the bed of the stream in one case was found showing little else for several rods but small fragments of white limestone. The mud also was of a calcareous character.*

*According to Dr. J. J. Bigsby Upper Silurian limestone is found in such large slabs and so abundantly at the mouth of Rainy river and westward from there that there is great probability that it exists widely in northern Beltrami county. But Dr. G. M. Dawson concludes that it has probably all been transported by floating ice at the close of the drift period, but admits the possibility of a Silurian area including the Minnesota shores of the Lake of the Woods. According to Dr. A. C. Lawson the glacial abrasion was toward the southwest. This limestone debris is wanting in the northern portion of the lake. It seems to the writer highly probable that Dr. Bigsby's judgment is correct, and that this limestone will be discovered *in situ* in the area mentioned.

The reader may consult: *Quart. Jour. Geol. Soc.* (London), viii, 400; *British North American Boundary Commission, Report on Geology, etc.*, 1875, p. 208: *Ann. Rep. Geol. Sur. Can.*, vol. i, 1885, 130CC.—N. H. W.

Mr. Joseph Sombs, of Park Rapids, who has spent considerable time cruising, also some time on a claim in T. 150–31, says that on the south side of Black Duck lake is much limestone along the stream for six or seven miles. That the masses of stone are not worn and the south bank of the lake is fifty or sixty feet high.

GLACIAL DRIFT.

Till, usually of a grayish cast, appears in the cut banks along the principal streams of this region. This may be seen occasionally along Rainy river and around Red lake. The deepest exposures we noticed along Clearwater river. One in sec. 6, T. 148–35, a few miles north of Bagley dam and nearly 100 feet in hight, exhibited the following section:

Section on the Clearwater river.

	Feet.
A slope consisting largely of gray clay or clay loam with pebbles; two or three wet layers below,	30
A stratum of boulders,	3–4
Gray till with limestone boulders, numerous limestone pebbles with a zone of ferruginous concretions,	30
The level of Clearwater river.	

At Bagley dam a section of the terrace is as follows:

Section at Bagley dam.

Fine sand obliquely laminated dipping to the east in strata 12 to 18 inches thick,	12–15
Till, imperfectly exposed, of similar color and contains large boulders,	12–15
Level of Clearwater river below the dam.	

About lake Bemidji a pebbly clay, evidently till, was exposed in the more abrupt banks along the south end of the lake. In the morainic portions described in the next section till is generally exposed though much obscured by weathering and surface action.

Moraines. The moraines crossing this county lie mainly in the southern third of the county and mostly traversing it from east to west. We shall find it convenient to indicate their position in order from north to south without regard to the order of formation. Moreover it should be remembered that in this timbered region it has been impracticable to locate them as confidently as has been done in open regions. We shall refer to the particular points in each, where observation has been made. Between such points there may be some chance for different interpretation as to their courses.

Red Lake moraine. This moraine is most prominently developed between the north and south members of Red lake east of the narrows. This has been studied by Mr. Upham. The fuller account is found in his paper which is subjoined. It is 150 to 200 feet in hight above the lake. It should be remembered that the lake is now twenty or thirty feet below the terrace, which marks a higher or lake Agassiz stage of the same. East of the lake it has not been explored in this county, but on or near T. 152–39, the Duluth and Winnipeg survey crossed a summit 1,318 feet

above the sea, which may be confidently connected with this moraine. According to the statement of Mr. Paquin, who surveyed the region, the ridge west of Red lake near the mouth of Oak creek, half way between the narrows and the outlet, extends northward about twelve miles. This ridge is said to be of uneven hight, varying from thirty to seventy feet, and bears upon it oaks and pines. Reference will be made to it under the head of beaches. We have already referred to Beltrami island the high ridgy region in the northern part of the county. The ridges have a northeast and southwest direction, at least in the eastern portion about the headwaters of the Winter Road river. This high land is reported to extend westward from that point between the head of War Road and the east branch of the Roseau rivers. There is a ridge rising forty or fifty feet above the surrounding country in the northern part of T. 162–38 lying in an east and west direction. We are informed by hunters and early settlers that a small ridge a few hundred feet in width separates a marsh connected with Buffalo point from a marsh extending west of Roseau lake near the international boundary. North of the international boundary extending west-northwest is a high ridge known as Pine ridge, which from a distance has the appearance of a moraine. We are inclined to consider these portions of the moraine forming two loops convex toward the southwest with a reëntrant angle or interlobular portion forming the east end of Beltrami island. The fact that some of these ridges have been modified by lacustrine action into beaches does not conflict with their earlier morainic origin. Perhaps it is this moraine with the bouldery deposits south of lake Winnipeg which Mr. Upham refers to as the extension of his Mesabi moraine.

The Hill River moraine. It will be remembered that in the account of Polk county attention was called to the prominent morainic strip along the north side of T. 149–39. It was suggested that a lacustrine modification of it turned northwest and north forming the divide west of Thief river. We are disposed to connect the moraine, as there reported, with the rough country continuing east and passing north of Clearwater lake. It crosses Sand river a few miles east, near the crossing of the Red lake trail. Its knobs rise about 120 feet above the water at that crossing. It has been crossed both by Mr. Upham and myself at about five or six miles southeast of Red Lake Agency, where some of its higher points rise about 150 feet above Red lake. It shows the typical features of knobs and basins with a difference in hight from twenty-five to thirty feet. It was crossed a few miles east by Dr. Norwood. His description of it may be found in Mr. Upham's paper. It seems not unlikely that the summit, from the Duluth and Winnipeg survey, near the southeast corner of T. 151–29, 1,442 feet above the sea, may result from the crossing of this moraine.

Wild Rice moraine. It will be remembered that in our treatment of Norman county we gave an account of a morainic strip ending near the highest beach of

lake Agassiz on or near T. 143–43, and its continuation north of east a little beyond the east line of that county, where it seems to coalesce with the moraine coming from the south and to pass with it northward, occupying the east range of townships of this county and Polk. It is well developed east of Fosston and is believed to turn east a little north of that point and connect with a morainic strip south of Four-legged lake, and north of Bagley dam and Buzzle lake. It continues east, passing north of lake Puposky where it shows scattered knobs fifteen to twenty feet in hight with an altitude of about 300 feet above Red lake. It has not been traced further.

Itasca moraine. Another moraine, which may be called Itasca moraine, though only partly equivalent of that so named by Upham, branches from this north of the Clearwater, runs southwest, east of Popple and curves sharply to the southeast, north of the Lower Wild Rice lake, and turns east, runs south of the Upper Wild Rice, thence passes the Mississippi six or seven miles north of lake Itasca, forms a very morainic strip along the east and south sides of that lake, thence southwest into Becker county. This is considered to have been formed by a lobe of ice coming from the east. Its irregularity is referred to an elevated preglacial ridge extending south of the Wild Rice lakes toward the east-southeast. Reference has been made to this difference of level in our treatment of Cass and Norman counties.

Turtle Lake moraine. This is a strip of hilly country with the hills rising fifty to sixty feet above the intervening lakes which are crossed by Turtle river north of Turtle River lake in the central portion of T. 148–32. High hills were noted also at the south end of Turtle lake, and again west of that point a few miles, and still more distinctly along Grant creek in the southwestern portion of T. 147–34, where knobs rising twenty-five feet above the surrounding sandy plains are not uncommon. Hills of unusual hight were noted by Mr. Garrison, south of the Mississippi and east of the Hennepin rivers. A similar range of hills not very compact but arranged in distinct ridges was noted west of lake Marquette, as has already been mentioned in our treatment of Cass county.

Lake Ketihi moraine. This is found rising in hills that are fifty or sixty feet in hight along the north and west sides of lake Ketihi. It appears well developed along the Mississippi at the Metoswa rapids, along its southeast course, in T. 146–32. This also was noted in our treatment of Cass county, as believed to connect with high land west of lake Kabekona and Leech lake.

Kames or Osars. Examples of this class of drift deposits have been seldom recognized in this county. A ridge rising about ninety feet above the general level, and elongated from northeast to southwest, was noted in the southeast corner of T. 146–36. It seemed not to be connected with other hills, and gradually declined in hight toward the west. Though no exposure of its interior was found, its

bouldery character seemed to indicate that it was an osar formed near the edge of the eastern ice-lobe, while it occupied the position of the Itasca moraine. Numerous narrow, low, bouldery ridges, ten to twenty feet high, were noted in the southeast corner of T. 148–37, and about Four-legged lake. Another isolated hill was noted on the south bank of the Mississippi, about two miles east of lake Bemidji. It rose forty feet or more above the level plain, and showed much gravel and sand in its structure.

The highest beach which we crossed was on or near the southwest corner of T. 159–33. Though this ridge was clearly modified into a beach, some features indicate that its original formation was that of an osar, or possibly a kame connected with a reënterant angle of the Red lake moraine as already suggested. Its isolated character, its declining in hight toward the west, and its unusually bouldery character all favor the view that it was originally an osar formed near the edge of the northern ice-lobe when it deposited the Red lake moraine.

An east and west ridge west of War Road river, rising about forty feet above the surrounding plain, may have had a similar history. Though it appeared to be a beach ridge, yet the explanation of its isolated position would seem to require its deposition from ice, and quite probably in the form of an osar. The series of hills south of Red lake, referred to as eskers by Mr. Upham, I find more intelligible as a moraine, the Hill River moraine. This is not inconsistent with the esker or osar-like character of some of them, for the drainage at the time was probably parallel with the edge of the ice.

A mile and a half to two miles south of the Red Lake Agency there are some sandy knobs rising twenty-five or thirty feet above the "pitted plain," which are apparently of the nature of osars, probably formed by streams along the ice-blocks.

Modified drift. The modified drift of the lake Agassiz region necessarily passes into, or is equal to, the lacustrine deposits which we mention under the next head. In the southern and more elevated part of the county the surface deposit at lower levels may be considered as formed by the action of waters attending the recession of the ice-sheet. These stratified deposits vary much in thickness, but rarely exceed ten or twelve feet. In the basin of the Mississippi it is very commonly quite sandy. The high terraces along the Mississippi and Clearwater rivers very possibly belong in large measure under this head.

Pitted plains. By this we mean a peculiar formation, often of considerable extent. It may be defined as a level plain in which are numerous irregular basins of various size, usually of considerable depth, with the sides quite abrupt. It seems natural to explain their formation somewhat as follows: There seems to have been, in some stage of the recession of the ice, an area, upon which the waters about the

edge of the ice-sheet deposited the finer material in a mud flat. The upper portion of these plains, so far as observed, is usually of fine clay with occasional small pebbles. In case masses of ice detached from the edge of the ice-sheet have become buried by this mud, it will readily be seen that eventually, when the ice has melted, there would be depressions of the surface, corresponding in area and depth to the size of the ice-blocks. We suppose that something of this sort has occurred over much of the area now covered with ponds and lakes, but we would restrict this name to areas that are particularly level, whether covered with sand, or, as more commonly the case, clay subsoil. Pitted plains, perhaps, are most finely exhibited along the south shore of Red lake. The descent from the water shed on the south to the highest beach of lake Agassiz in this region is by a succession of two or three terraces. The edge of the lowest one seems to correspond quite closely with the lowest beach found a little south of the present shore of Red lake, and about forty feet above it. The moraine, which we have called Hill River moraine, forms the edge of the next terrace, which is not as even as the lower one. The Wild Rice moraine marks the edge of another rise which is the highest. Between this and the preceding the difference in hight is slight, especially about the head of Turtle river. The lowest of these plains is one which especially deserves the name of "pitted plain." It is well exhibited a few miles south of the Red Lake Agency. The basins in it are usually twenty to twenty-five feet below the general level. It is more sandy than the last two. This lower plain extends, as may be easily inferred, indefinitely east and west, and has a breadth of two or three miles. The second one rises from 90 to 100 feet above the lake and is much more clayey. It is more than usually fertile, being covered by a vigorous growth of sugar maple, oak, white pine, and poplar. It also extends indefinitely east and west between the inner edge of the Hill River moraine and the till surface which slopes upward to the south. The line between the two is not always readily ascertained. The surface is not so uniform, and the basins upon it are less regular in size and in depth. The lower of these plains seems to have been formed by the mud left by the recession of the ice-sheet along the edge of lake Agassiz during the stage of its highest beach in this region. Both would seem to have been similarly formed along the southern edge of the ice-sheet, the second when it occupied the position of the Hill River moraine. At that time the water was probably discharging toward the west with considerable current, and therefore left the surface in a less level condition.

Striæ. As before mentioned, the exposures of crystalline rocks in the northern part of the county usually exhibit glacial striæ. They rarely are large enough to be called grooves. They are commonly a few inches in length and vary in breadth from fine lines to half an inch. The directions as given below (marked M) were taken with a magnetic needle; where that failed, they were taken by the azimuth of the

sun. In the former case we allowed 11° or 12° for the eastward variation of the needle; in the latter case, not having access to complete azimuth tables, the directions given may have an error in some cases of two or three degrees:

Cormorant rock,	south 73° west
Cormorant rock,	south 32° west
Rocky point,	south 62° west
Rocky point, south 27° west, and mostly	south 52° west
Long point,	nearly due south (M).
Zipples, by the house, south 71° east, and south 79° east, on the east side of the knob.	
One-half mile west,	south 33° west, and south 20° west (M.)
One-half mile east of Rapid river,	south 42° and 50° west

We add a few belonging to our area from the report of Dr. A. C. Lawson, on the Lake of the Woods region.

Northwest angle inlet, McKay island, south 58° west to	south 60° west
Bucketé island,	south 45° west
Flag Island point,	south 50°, 52° and 37° west

On the southern promontory which includes Rocky, Long and Stony points, of the previous table.

Northeast point, which is probably Stony point,	south 33° west
Northeast point, which is probably Stony point,	south 70° west
Northeast point, which is probably Stony point,	south 35° west
Northeast point, which is probably Stony point,	south 10° west
Northeast point, which is probably Stony point,	south 65° west
Cormorant rock,	south 33° west

RECENT DEPOSITS.

Alluvial flats. These are found along the principal streams, as the Mississippi and Turtle rivers, a little above the level of the water, but usually are of limited extent.

Terraces. Under this head we recognize those of streams and those of lakes. Recent forms of both these kinds are unimportant. They are but a few feet above the alluvial plains, and no very distinct line may be drawn between them and the terraces which really belong to the modified drift. Along the Mississippi around Cass lake a sandy terrace rises twenty-five or thirty feet above the level of the water. It is quite even-topped, sometimes wide and sloping abruptly to the water's edge or the alluvial flat. The same are found at less hight above the water around lake Bemidji. Terraces of these hights should be more properly referred to the modified drift.

Swamps. Very much of the surface of the county is covered with swamps of various kinds. It is not unlikely that nearly one-half of the whole area of the county is covered by swamps and lakes. They are usually of slight depth and owe their existence quite as much to the abundant growth of moss as to the uneven surface of the country. Sphagnum bogs may even climb slopes of 5° for scores of feet.*

Quite an important factor in their formation, especially in the basin of lake Agassiz, is the work of beavers. On quite gentle slopes they extend dams many rods in length to hold the water. So also because the surface is so nearly level, the

*SHALER. *Tenth Annual Report, U. S. G. S.*, p 286.

damming of a stream will sometimes throw many square miles into swamp. The character of the vegetation of the swamp depends mainly upon the depth of the water. Where it is over five feet in depth it is apt to be covered with what is commonly called "muskeg," that is, a thick growth of moss which fills the water sufficiently to hide it but yields to the foot so that one may sink to the knees or waist in the water, and a trembling motion is given to the surrounding surface sometimes for several yards. These frequently show scattering grass and small tamaracks on the firmer points. In the muskeg south of O'Brien lake it was noticed that the mossy surface was traversed by nearly equidistant strips of scattering tamarack extending in a northwest-southeast direction several rods apart. This may have been due to incipient beaches formed upon the bottom of the basin. Where the water is shallower and the footing firmer bushes begin to appear, usually of small growth. Where the ground is still firmer, dwarf tamaracks will appear, and so from this stage to the firm land covered with jack pine there is usually the succession in order as follows: of dwarf tamarack, full grown tamarack, spruce or cedar and pine. The cedar, or arbor-vitæ, seems to prefer the purer water of springy regions, while spruce may grow where the water is less pure. Both of them grow also upon dry ground. Where the swamp is connected with a stream and abounds in decomposing matter, alders flourish. Where the moss is very abundant the spruces are of a form known as "cat spruce," from their being frequented by rabbits and lynxes. Whether it is a distinct variety or a dwarf form of the common kind I am unable to say. When the water increases in depth, tamaracks may be killed out and on drier land the cedars and spruces may become replaced by tamaracks.

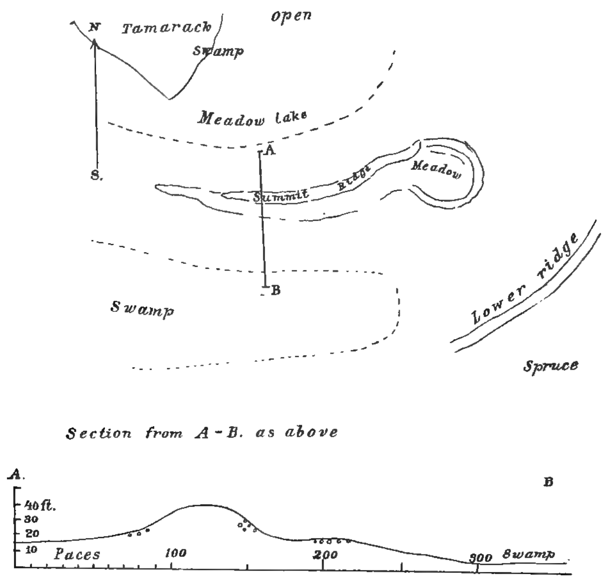
Lacustrian formations. Beaches. Around Red lake there are numerous beaches which cover the gentle slopes, as for example on the east side of the north part of the lake, rising one above another at intervals of a few rods to the hight of ten or fifteen feet above the present water level. They are rarely extensively or thickly developed and rise only a foot or two above the average slope.

Below the surface of the water incipient beaches in the form of bars may be found, especially along sandy shores, extending parallel with the shore. Several of these may be sometimes traced by the growth of bulrushes. In this way they may be traced to a depth of ten or fifteen feet below the surface.

Boulder walls. At certain points around Red lake, and less prominently in smaller lakes, the abrupt shore of the lake is faced with a thick deposit of boulders, sloping at an angle of from ten to twenty degrees, and from ten to twelve feet above the water to as great a distance below. They are probably due, as has been before pointed out, to the accumulating action of floating ice and prevalent winds, with the occasional assistance of thrusts from expanding ice.

Ancient beaches of lake Agassiz. Mr. Upham, in his discussions of lake Agassiz, recognizes what he calls the Herman beach or beaches, which mark the highest level of that lake in its southern and western portion. He has traced the five or six beaches of this group without question as far north as Maple lake, in Polk county. He has also, in the paper on Red lake, which is subjoined, and also in a note in the American Geologist for 1893, vol. xi, p. 423, assumed that this highest beach of the Herman series has been recognized south of Red lake at an altitude of about 1,210 feet; also that the beach recognized on the Duluth and Winnipeg survey at about 1,215 feet is the same. To this conclusion there appear the following objections: First, if the rise in the Herman beaches continues eastward and northward, at the same rate which Mr. Upham published in Bulletin No. 39 of the U. S. Geol. Survey, it would be around "Beltrami island" fully 1,300 feet, and south of Red lake about 1,260. Second, the apparent junction of one of these beaches with the Hill River moraine has been noted and described in the geology of Polk county. Third, from general principles, strengthened by the rise of the beaches toward the east, we infer that the recession of the ice-sheet was toward the northeast, and that therefore it lingered longer over the Red lake region than further west. It is probable, therefore, that the beach at an altitude of 1,215 to 1,220 around Beltrami island is one of the lowest of the Herman beaches or the highest Norcross; that the summit beach which we have surmised was once an osar, is one of the first of the Herman beaches to extend into this region, but probably not the highest. Assuming that the beach at 1,215 to 1,219 of the Duluth and Winnipeg survey corresponds to a certain well-marked beach, rising to a corresponding hight above the general swamp, we confidently reckon that the summit beach is one of the hills referred to in the profile of that survey as rising 1,283 feet, and that it is probably the third or fourth of the Herman series. A rough map and section of this beach are given in figure 15. It is natural that the survey should avoid the highest beaches of Beltrami island, and from the reckoning previously referred to it seems reasonable to think that, if at the formation of the first Herman beach the edge of the ice-sheet was along the Hill River moraine, it may have receded so as to uncover this high land by the time of the formation of the third or fourth beach. Moreover, we should correlate the summit beach with the higher beach shown around Red lake, about forty feet above the water. As may be readily inferred from the previous pages, no extensive tracing of beaches has been made in this county. The map indicates portions of beaches to which we have already referred. Along the railroad survey mentioned, ten or twelve beaches were passed on the slope facing Lake of the Woods between altitudes of 1,080 and 1,215. A similar number were also traversed from summit beach to Rainy river. They were mostly ill-defined and fragmentary, but showing distinctly elongated and approximately parallel low ridges of sand

rising one to three feet above the average slope. One interesting feature connected with them is the increase of moisture, even to occasional open ponds along the southwest sides of the ridges. The high ridge, on the trail from Jadis to War Road river should properly be correlated with the Jadis ridge or Campbell beach. It has an altitude of about forty feet above the surrounding plain, or about 1,080 or 1,090 feet above the sea, which would correspond well with the estimated hight of the Campbell beach.



Plan and section of Summit Ridge Tp. 159 - 33

FIG. 15.

The probable geological history of Beltrami county. In this section we shall simply briefly gather together in a consistent whole the suggestions which have been made in previous pages bearing upon this subject.

As far as concerns the Archean and Paleozoic history this region is similar to that of the surrounding counties. It seems not unlikely that during the early Paleozoic it may have been mainly covered by the sea. The abundant limestone in the drift and the local accumulation of the boulders at certain points seem to indicate that limestone of that age is not very far below the surface, especially in the southern part of the Red lake basin.

During the latter part of the Paleozoic it was probably dry land, but from the occurrence of the Cretaceous clays in the county east along Bowstring river there is little doubt but that much of this county is underlain by similar formations; and that at that age it was largely covered again by the sea. It seems not improbable that the core of Beltrami island may be of Cretaceous shales of the Colorado period similar to those found in Turtle and Pembina mountains. This view is strengthened by the reported discoveries of coal in the northern part of the county. It is

probable, however, that they are fragments of lignite coming from beds which are very thin and impure. They are quite certainly not derived from Carboniferous strata, for no fossils of that age have been found in the drift south and west. During the Tertiary the region was probably dry land and subject to great erosion. This is indicated by the irregularities of the preglacial surface in the northern part of Lake of the Woods.

During the Quaternary it was covered for a long period with the continental ice-sheet. At its maximum stage this may have been several thousand feet in thickness, with its general motion from the northeast. We are more interested, however, in the closing scenes of this age and in the effects of the movements of the ice in its recession. The first part of the county to be uncovered was doubtless the extreme southwestern corner, which is also the highest region of the county. At the time of the formation of the Itasca moraine, according to our view, the lake Superior ice-lobe covered the whole course of the Mississippi river, with the exception of lake Itasca and its channel the small creek in the southern part of T. 144-36. The Red lake ice-lobe covered the whole northern part of the county as far south as the Wild Rice moraine, which includes the basin of the Wild Rice river, and farther north. These two lobes were probably confluent as far southwest as Mud lake, and the water from their inner slopes discharged southwest through Otter Tail and Buffalo rivers, and very soon after through the Wild Rice river. The upper waters of the Mississippi at this time turned westward, first by the before mentioned creek and later through Moose creek to Upper Wild Rice lake. At a later stage the Red lake lobe, whose melting was probably hastened by the waters of lake Agassiz, had receded to the Hill River moraine. At the same time the lake Superior lobe was probably forming the Turtle Lake moraine or possibly the Ketihi Lake moraine. It seems not improbable that the Turtle Lake moraine may correspond to an imperfectly morainic strip lying between the Wild Rice moraine and the Hill River moraine, which we have associated with the former. At this stage of the Turtle Lake moraine the Mississippi may have discharged along the line of the Little Mississippi and Clearwater. While the ice was forming the Ketihi Lake moraine, the drainage from the ice front seems to have been unusually sluggish, and to this may be ascribed the wide extent of level country surrounding lake Bemidji, Turtle lake, and the region as far north as the Wild Rice River moraine. At that time the drainage of the Mississippi and of western Cass and even northern Hubbard county may have been northward by way of Grant creek and Clearwater river, and through the low ground between Bemidji and Turtle lakes and northward toward Red lake along Mud river. This view is favored by the channel, as before mentioned, connecting Lac du Mort and lake Julia. At the same time water may have drained from the east branch of

Turtle river northward into the headwaters of Black Duck river. If we are correct in our reasoning, at this stage the ice had not retired from the Hill River moraine. After this point the lake Superior lobe retired beyond the limits of the county, but the Red lake lobe still occupied the northern part of the county.

At the stage recorded by the Red Lake moraine we may conceive that lake Agassiz occupied the region to the hight of the highest beach south of Red lake and washed the front of the ice as it extended just north of the south portion of Red lake and turned northward from the vicinity of the mouth of Oak creek to the south shore of Beltrami island, which was then beginning to be uncovered. It also was in contact with the ice northwest of that island, probably between War Road river and the Roseau. We may reasonably suppose that the ice stood at this stage for some time because of the hight of the moraine between the two portions of Red lake. That the material was not much accumulated northwest of that locality is probably due to the leveling influence of the waters of the lake, both by the action of the waves and the transporting effect of the floating ice. As we have argued in another place, the absence of boulders from the beaches does not seem to us valid reason for supposing that icebergs were not floating in the lake at this time. The last portion of the county to be covered by the ice was doubtless the northeastern corner.

Differential elevation. Then came the gradual rise of the land toward the northeast, which was marked by the formation of succeeding beaches which were partly due to this cause and partly to the cutting down of the outlet at lake Traverse. In the falling of the water there seems first to have been an extension of Beltrami island along the line of the Red Lake moraine, leaving a much larger extension of Red lake than at present. The rapid succession of light beaches along the slope toward Rainy river is probably due to the more rapid rise in this portion of the lake bottom. Lake Agassiz doubtless receded last from this county in the northwest corner.

Red lake for many years after was probably much more extensive than at present. The region west of the South lake and several townships north and east of the North lake was probably open water until quite a recent period.

ECONOMIC FEATURES.

Of the subjects under this head we can speak but briefly, for investigation has not been carefully made.

Vegetation. The whole county is covered by forest growth with the exception of several square miles of prairie along the Mississippi between Moose creek and the Little Mississippi; also near the Upper Wild Rice lake. These seem to be the result of forest fires and from appearances it seems not improbable that the grass

will be of permanent growth. A somewhat similar area of prairie was crossed two or three miles in width, north and west of the west branch of Winter Road river. An interesting fact in this connection is that a cedar swamp had been the character of the country burned. As a result it seemed probable that the grass had become well established and would prevent the growth of moss and the return of swampy conditions. The region west of the South lake between Red Lake river and the Clearwater is mostly open and somewhat covered with grass, but marshy. In this respect it does not differ from numerous open marshes, often of wide extent, through the north half of the county.

Pine. The three prevalent species of pine are well represented in this county. The black pine prevails upon the sandy portion in the southern part of the county, often covering quite extensive areas, as between lake Bemidji and the Little Mississippi. The red pine is also found in groves of large and valuable timber mostly in the southern and higher portion of the county. The white pine was noticed particularly prominent upon the clayey flat lands, or pitted plains south of Red lake. The water-shed between the Mississippi and Red Lake valley abounds in large and valuable groves of white pine. The Red Lake moraine and the region between the two portions of Red lake is also abundantly supplied with white pine.

About Beltrami island, upon the higher land, white pine was found in limited quantity. As a rule the drier portions there are covered with the black pine, and for some reason that portion of the county seemed especially subject to windfalls. It was found much easier traveling through the swamps than upon the dry ground for this reason.

Along the streams flowing into the Rainy river white pine abounds on the rich ground next the stream. As before mentioned, considerable pine has been cut and floated down the Roseau river.

Deciduous trees. Of these trees the poplar or aspen is the most widely distributed. It abounds on clayey land throughout the region, particularly on the low ridges and swamps and on the higher or clayey pitted plain south of the Hill River moraine. It is well represented in numbers and in size along the valley of Rainy river in company with the kindred species, cottonwood and balm of gilead. Oaks are found in occasional groves along the Rainy river valley and in the southwestern portion of the county. None of conspicuous size were noticed.

Of the maples, the sugar maple abounds upon the sandy plains between the two portions of Red lake and upon the clayey flats south of Red lake. Upon the highest plain, forming the water-shed between Red lake and the Mississippi, the hard maple is especially common. Moose wood abounds in the swampy region north of Red lake. Basswood, white elm, and birch are widely distributed upon the drier land. Ash is common on richer and moister lands.

Hay meadows. These are found in dry lake basins and on margins of large lakes, also on alluvial bottoms along the principal streams. The grasses most commonly noticed are sorts of red top and blue joint.

Drainage. We have alluded to the way in which a cedar swamp in the northern part of the county seemed to have been transformed into a dry fertile prairie as a result of a fire. In traversing the region between Thief River falls and Rainy river no very deep marshes were found. Frequently the water was deep enough to produce open marshes, but even in such cases, not infrequently, boulders were found rising above the surface, and several trials seem to indicate that sandy bottoms could generally be obtained within three or four feet of the surface. We have alluded to the way in which beaver-dams and the growth of moss contributed to the retention of water in the region, and the prevalence of swamps. It seems entirely practicable that large areas, now covered by a swamp, may be drained without much difficulty, and that such portions could be reclaimed and fitted for agricultural purposes. The slope of the country is such that by the deepening of existing channels, and the removal of fallen timber, most of the region north of the Red lakes could be drained. The dominant formation beneath the surface seems to be a boulder clay, thinly covered with sand.

Water-power. There is considerable fall in the Mississippi, between lake Itasca and lake Bemidji, so also in the Clearwater, between Bagley dam and Clearwater lake, and along the upper portion of the streams flowing north into Red lake. So, also, there is considerable descent in the middle portion of the streams flowing into Rainy river and Lake of the Woods. The extensive level areas provide for the storing of limitless supplies of water. In no case, however, would many feet of fall be practicable.

Climate. Of this we need to say little except that the northern part of the county seems especially moist. During seventeen days in July, 1893, which we occupied in crossing the region north of Red lake, there were but two days in which there were not considerable showers. The name given to Rainy river seems to have had reference to a similar character of the climate noticed by early voyagers.

Fish and game. The whole county is naturally abundantly furnished with game, and its waters are unusually well stocked with fish. Though the Ojibway Indians have occupied Red lake for many years, we found upon the shores of the lake frequent track of caribou, moose, deer, bear, and the region north of Red lake was traversed in all directions by the paths of moose and caribou, many of them showing the recent passage of animals. The Indians do not venture into the swamps during the summer, and this affords abundant protection to these large animals. Along the larger streams the occurrence of frames for drying meat, and of poles

bearing on the top a strip of moose skin, or a flat-topped stake, indicating the killing of a bear, signify the frequency with which these large animals are taken. Though we rarely saw game in the swamps, because of the noise which gave warning of our approach, we at times, while in a canoe, came upon moose that seemed not particularly alarmed by our presence. Lake of the Woods is particularly famous for its sturgeon fisheries, which are conducted on a scale reminding one of the fisheries along our Atlantic coast. By means of nets and pounds they are taken by the boat-load, and schooners of considerable size are employed in the business. Caviar is made and shipped in large quantities to eastern markets and even to Europe. Whitefish, pike, pickerel, and many other species abound in Lake of the Woods and Red lake, also in most of the lakes throughout the county.

Minerals. No minerals of value have yet been found in paying quantities. As before stated, rumors of coal in the northwestern part of the county have been reported which may develop the occurrence of thin beds of lignite in that region. Quite likely, however, only fragments in the drift will be found. That there is no coal of Carboniferous origin may be confidently affirmed from the fact that no fossils of the Carboniferous age have been found anywhere in the region.

Gold. As we have already hinted, this may be found in the Archean rocks around Lake of the Woods, particularly in the "northwestern angle." Some fine specimens have been found near Rat Portage. Traces of copper have also been found in the Archean rocks on the north side of the Lake of the Woods, but both of these have been found in the "Huronian" slates, while upon the American side of the lake granites are more prevalent.

Iron. It may seem probable from the trend of the geological formations and their nearness on the east that the iron ores of the Vermilion region might extend into this county, but there is little or no probability of its being found, for the whole region is thickly covered with drift.

GEOLOGY OF THE REGION AROUND RED LAKE AND SOUTHWARD TO WHITE EARTH.

By WARREN UPHAM.

Altitude and Area of Red Lake.

The altitude of Red lake, determined by the survey for the Duluth & Winnipeg railroad, is 1,172 feet above the sea. On Beltrami island of the glacial lake Agassiz (Am. Geologist, vol. xi, pp. 423–425, June, 1893), lying north and northwest of Red lake, the profile of this survey shows the highest beach of the glacial lake to be 1,215 feet above the sea.

According to the township plats of the United States government surveys, done in the years 1890 to 1892, the length of the south part of Red lake is about twenty-five miles, and its mean width about nine miles; and

the length of the north part of the lake is approximately twenty-four miles, with a mean width slightly exceeding eight miles. These dimensions give a total area of Red lake, measured, on a plat combining the township surveys, of about 441 square miles. It is the largest lake contained wholly within the state of Minnesota, being more than twice as large as Mille Lacs, which is next in size. A strait nearly one mile wide, called "the narrows," connects the two parts of the lake. The original width of this strait was about two and three-fourths miles, but it has been thus reduced by the action of winds and waves, which have formed narrow spits of sand, jutting out more than a mile from each shore.

Adjoining Country and Tributary Streams.

Notes taken during a canoe voyage in September, 1885, along the entire shore line of Red lake, while engaged in exploration of the area of the glacial lake Agassiz for the United States Geological Survey, supply the following descriptions of this lake and of the surrounding country.*

The maximum depths of Red lake are reported to be forty to fifty feet. Its northern part becomes frozen in winter earlier than the southern part, indicating that the latter has a greater average depth. Its shores are mostly low, varying from ten to thirty feet above the lake, or only one to three feet in the swamp north of its northern part. The only considerable elevation near this lake is the tongue of land two and a half to three miles wide, extending ten miles east from the narrows, which is a belt of morainic drift 100 to 200 feet high. The view from no portion of Red lake extends to any great distance, the farthest land visible being some six miles away in the direction southeast from the Agency toward Cass and Leech lakes.

The whole country surrounding Red lake is wooded. Areas of till are covered by a dense growth of deciduous trees, with occasional groves of white pine; and a valuable forest of this pine crowns the ridge east of the narrows. A more scanty growth of dwarfed black oaks and the Banksian and red pines occupies tracts of modified drift, as at the Agency and for several miles thence southward. The swamps are also sparingly wooded, their species being tamarack, balsam fir, and arbor-vitæ. Only a few small tracts, from one to a hundred acres, have been cleared for cultivation. These are partly in the vicinity of the Agency, and partly near the Ojibway village, which is one mile south-southeast from the narrows.

Sometimes a sand-bank off the extremity of the northwestern sand spit at the narrows is exposed to view as a low island a few inches above the water; but at the time of my visit this was not in sight, as the lake was at an uncommonly high stage, probably three feet above its lowest level. It has no other island, nor has it any noteworthy peninsula nor cape, excepting those which divide the two parts of the lake. Many portions of its margin extend several miles in a straight or gracefully curving course, with no indentation nor outstanding point.

Eighteen or twenty streams of sufficient size to be named by the Indians, and some ten smaller creeks, flow into Red lake. The largest of these are Sandy river, Big Rock creek, Pike creek, Mud river, Black Duck river, and Battle river, which enter the south part of the lake in this order from west to east and north; and, continuing in similar order, Big Sand Bar creek, Tamarack river, Poplar river, the East and West Two rivers, and Wild Rice river, tributary to its northern part. Notes of these and of all the smaller affluents which were observed in this exploration, with descriptions of the shores, the various drift deposits, and the timber, are as follows, in the order of our canoe voyage, starting from the Agency eastward and continuing around the lake. It was my hope that exposures of the bed-rocks underlying the drift would be found; but instead it seems certain that no such outcrop exists in this region.

From the Agency around the east part of the southern half of Red Lake to the Narrows.

The Indian name of the stream at the agency is Pike creek, rendered Gold Fish creek by Beltrami; but by the English residents it is more commonly called Mill creek. A saw and grist mill, having ten feet head, is built on this stream about a quarter of a mile from its mouth. The mill pond, which is about twenty feet above Red lake, is twenty to forty rods wide and extends a mile to the east, parallel with the shore of the lake. Pike creek below the mill is ten to twenty feet wide and six inches to one foot deep. Its sources, according to Rev. F. W. Smith, are a series of three or four lakelets, the lowest of which, lying on the southwest side of the road to Cass lake, is called by the Indians Little lake, but by the white men Ten Mile lake, from its distance of about ten miles south-southeast of the Agency. The highest, called Cranberry lake, has quite irregular outlines, lying mostly in secs. 34 and 35, T. 150-34, with a length of about a mile from northeast to southwest.

Red Lake Agency is situated near the middle of the south side of the south part of Red lake. It is on a plain of sand and gravel, about thirty-five feet above the lake, lying close east of Pike creek and north of the west end of the mill pond, nearly a quarter of a mile from the shore of Red lake. This village includes about twenty-five houses and probably a hundred inhabitants, nearly all of them Ojibways, not counting the sixty or seventy Ojibway children in the boarding school.

About two-thirds of a mile east from the mouth of Pike creek we passed a point that stands out very slightly from the nearly straight trend of the shore, which is N. 85° E.† Many granitic boulders up to six or eight

*My companions in the voyage were two Ojibways, Roderick McKenzie and William Sayers, who propelled the canoe and performed the work of camping and cooking. They proved themselves expert with paddle and rifle, and several times added game to our bill of fare. Both had received a fair education and could converse well in English, though more familiar with their native language. Mr. McKenzie, by his acquaintance with the Indians about the lake, was specially serviceable in obtaining information as to the names applied by them to streams and points of land along the lake shore, and the translations of these are given in the following pages. This canoe voyage occupied six days and extended along the entire shore of the lake, a distance exceeding one hundred miles.

†The bearings taken in this reconnaissance, and in part noted in these pages, are corrected so as to refer to the true meridian. The magnetic variation here is about 13° to the east of north.

feet in diameter border the shore here for an eighth of a mile or more, being piled wall-like against the foot of the bank of sand and gravel which rises about twenty-five feet. These boulders are derived from underlying till. The same plain of modified drift continues several miles east, generally forming a sandy beach; but boulders scattered here and there along the shore, occasionally in great abundance, show the near presence of till beneath.

Two miles east from the Agency is a slightly projecting point of sandy shore, with no boulders, from which the land rises gently in forty or fifty rods to a hight of about thirty feet. This is called Kahgone's point, from an Indian living there; the meaning of this name is "young porcupine." Magnesian limestone pebbles make up two-thirds of the gravel here. A depth of three feet of water is reached ten to fifteen rods from the shore. Near this point, and in many other places about the lake, little ridges of sand and gravel, one to three feet high, have been pushed up from this shallow water by the ice; but no specially noteworthy ice-formed ridges were seen.

A small creek, having a length of four miles, enters the lake a half mile east of Kahgone's point. From a fourth to a half of a mile beyond this creek, a steep bank of till forms the shore, occasionally showing an imperfect stratification to a depth of five or ten feet below its top, which is twenty-five to thirty feet above the lake. Here and eastward many boulders of all sizes, to six or eight feet in diameter, line the shore. Nearly all of them are Archean, being mostly granite and gneiss, with a few of hornblendic and micaceous shists. Though magnesian limestone, such as outcrops near Winnipeg, has supplied a large proportion, usually from one-third to two-thirds, about this whole lake, only rare boulders of this rock are observable among the multitudes of Archean origin, probably not averaging more than one in five hundred. This is due to the more massive condition of the latter, enabling them to withstand much wearing and crushing, by which the limestone, with its joints and planes of bedding, becomes broken into small fragments.

Near the chief's village, about four miles east of the Agency, is a slightly projecting point, called the Chief's point. It is formed of till, which rises steeply twenty-five to thirty feet above the lake. Indian cornfields were seen on its top, in small clearings of the forest.

Mud river, called the Red Lake river on former maps, and Grand Portage river by Beltrami, enters the lake about a half mile east of the Chief's point. This is a considerable stream, larger than Pike creek, but smaller than Sandy river and Black Duck river. It is about fifteen miles long, flowing north-northwesterly from sources near Turtle lake and river, which are tributary to Cass lake. Its head-stream passes through lake Puposky or Papashkwa, named on the township plats Mud lake, two miles in diameter and containing a large island, and through two lower small lakes called Wild Rice lakes. Near the mouth of Mud river and thence eastward to Big point, the shore is till, rising gradually in a quarter of a mile to a hight twenty to forty feet above the lake. It bears a heavy growth of hardwood, interspersed with occasional tall white pines, and has much fallen dead timber.

Big point, a broad swell of the shore, standing out perhaps an eighth of a mile beyond the general outline westward, but little from that eastward, is a mile east of Mud river. It has a sandy and swampy low shore, spruce and elms being conspicuous in its forest. Here, and eastward to Black Duck river, the land bordering the lake is till, but it lies so low that no portion of it has been undermined and washed away, and therefore the shore has none or only very rare boulders.

In the distance of about six miles from Big point to Black Duck river, four small creeks enter the lake, bordered by tracts of marsh grass along the lower part of their course. On these meadows we saw many stacks of hay which had been put up by the Indians, and the name Hay creek is applied to one or more of these streams. The eastmost of them has its mouth only ten rods west of the mouth of Black Duck river. Hay is also cut by the Indians on the meadows of this river, and of nearly all the streams about Red lake.

Black Duck river enters the most southeast part of the southern half of the lake. It is called Cakakisciou river on Beltrami's map, and Cormorant river on Nicollet's and later maps; but it seems to be known to the English-speaking residents only by the name of Black Duck river. This stream is said to be about twenty miles long, flowing in general from the southeast, although its course for the last three miles is from the northeast. It is one of the four largest tributaries of the lake; the others that rival or slightly exceed this are the Tamarack, Wild Rice, and Sandy rivers. The principal tributary of the Black Duck river, coming in from the northeast about three miles from the mouth of the Black Duck, but only one mile back from the lake shore, is now named on the township plats as the Cormorant river.

Within the half mile next southwest of the mouth of Black Duck river, the shore turns from the course a few degrees north of east which it holds from Big Rock creek to the Agency and to this curve, about twenty miles, and gradually changes to a course only a few degrees east of north, which it holds for the next six or seven miles north, at the end of which distance it again curves within about a mile to a course nearly due west, thus giving to the east end of the south part of the lake a peculiar truncated outline.

Along the south side of the lake eastward from the Agency, much of the shore is twenty to thirty feet high, and the surface slowly rises in five or six miles to an elevation 100 to 125 feet above the lake; but the shore of the east end of this part of the lake is all low and does not attain any considerable hight within the few miles seen from the lake. Its highest portion lies eastward from the mouth of Black Duck river, where it rises thirty or forty feet at the distance of a mile. Hay meadow and marsh border the lower part of this river, which for two miles next to its mouth flows in a meandering south-southwesterly course within 30 to 100 rods from the lake.

Stratified sand and fine gravel, belonging to the modified drift, with no boulders, form the entire eastern shore, having a hight only five to ten feet above the lake for nearly five miles north from the mouth of Black

Duck river to a quarter of a mile north of Battle river, beyond which its elevation for about a mile is twenty to thirty feet, succeeded farther north, about the most northeastern part of the shore, by another low tract.

There is a portage of about thirty rods from the lake to Black Duck river nearly one and a half miles north from its mouth. It crosses an ice-formed ridge of gravel and sand six to eight feet high and about ten rods wide, which is wooded. East of this the river flows through a hay meadow which is seen to extend three-fourths of a mile to the north and a half mile or more to the south, with a width of about a half mile. All the land surrounding this meadow is low, nowhere exceeding twenty feet above the lake, and is covered by deciduous trees. The only coniferous species seen in this view are occasional belts of tamarack along the margin of the meadow.

Two dome-shaped knolls of sand, about fifteen feet above the general level, lie close to the shore, one a third of a mile and the other about a half mile north of the Black Duck portage. From a quarter to a half of a mile farther north many such sand mounds border the shore, their crests being twenty to thirty feet above the lake. All these are dunes heaped up by the wind, but they are not now undergoing much change, and have mostly become covered with trees and bushes. Beyond this tract they continue northward in diminishing numbers and size for more than a mile.

Battle river enters the lake from the east-northeast about a mile north from the most northern dunes. It is of nearly the same size as Big Rock creek and Mud river.

In the curve to the north shore of this part of the lake the area of stratified sand and gravel is succeeded by till, which reaches thence to where the shore bends to the north about two miles south of the narrows. The south and north parts of the lake here are divided by a prominent morainic tract nearly ten miles long, which decreases in width from about four miles on the east to two and a half miles near its west end. In its eastern half it rises to a hight of 75 to 100 feet; but the highest portion of its western half, three to five miles east-south-east from the narrows, is elevated 150 to 200 feet above the lake. This massive ridge is till with a somewhat uneven surface, having knolls and small ridges twenty to fifty feet above the adjoining depressions. Much of this northern shore of the south part of the lake has been eroded so that it rises steeply ten to thirty feet, and abundant boulders are strown at the foot of the slope and accumulated in a wall-like border about projecting points.

Canoe portages are sometimes made from the northeastern curve of the south part of the lake to the vicinity of Poplar point on its northern part.

Close to the shore the forest is mainly of deciduous species, including sugar maple, bur and black oaks, elms, hackberry, basswood, poplar, and ironwood; but the higher part of the morainic belt bears a majestic forest of white pine, which probably averages two miles or more in width and is the only extensive tract of this valuable timber near the shores of Red lake.

Coasting along the shore from the curve above mentioned to the narrows, two small points are passed about one mile and two and a half miles from the east end of the lake, and a half mile farther west is a small tributary called Sucker creek, the only stream noted along this distance. About three and a half miles west of this creek is Elm point, and nearly two miles beyond this we passed the more conspicuous Uninhabited point, so named by the Indians because of ancient clearings along the shore for a mile to the east, where in some former time, probably a century or longer ago, the Ojibway people had a village and cultivated fields. Their bark lodges and more permanent log-houses, with patches of corn and potatoes, were seen here and there all along this shore from its most eastern portion to the narrows.

Beyond the Uninhabited point the shore trends west-northwest past Pelican, Halfway, and Rabbit points, successively about three-fourths of a mile apart. Halfway point is marked by an unusually large angular block of granite or gneiss at the water's edge. About a mile northwestward from Rabbit point is Sand Cliff point. The base of this is the usual wall of boulders, derived from erosion of till; but its upper part, rising steeply from near the lake level to a hight of seventy-five or eighty feet, is levelly bedded sand and fine gravel. From ten to thirty rods east of the point this deposit of modified drift is destitute of vegetation, so that it is conspicuously visible from the south shore. This locality was the scene of the fasts, vigils and incantations of medicine men of the Ojibways in former times.

Boulders line the shore for nearly a half mile northwest from the Sand Cliff point, but the till supplying them is covered by knolly deposits of sand and gravel, which rise in small plateaus and ridges, apparently trending mostly from east to west, their crests being fifty to seventy-five feet above the lake, with intervening hollows, thirty to fifty feet deep. These appear to belong to the morainic belt, and they abut eastward upon its higher land, which is chiefly till.

Next to the northwest a plain of sand and gravel, bearing no forest, and perhaps in part natural prairie, about twenty five feet above the lake, extends two-thirds of a mile or more, diminishing from a third to an eighth of a mile in width. On this tract, about a mile south from the narrows, is the principal Ojibway village of Red lake, consisting of forty or fifty lodges. Some fifty acres of corn, several acres of potatoes, and a good supply of squashes, were nearly ready for harvest here. This village was represented fifty years ago on Nicollet's map,* which was of so early date that it does not show St. Paul, Minneapolis, nor any other city or town in Minnesota.

A narrow spit or hook of sand and gravel, mostly fifteen to twenty feet above the lake, projects northward into the narrows; its low extremity, about a quarter of a mile long and only three to five feet high, is curved northeastward. A third part of the gravel here is limestone, the remainder being mostly granite and

* *Geology of Minnesota*, vol. i, plate 7, facing p. 67.

gneiss; its largest pebbles are three inches in diameter. From this southeastern cape or point of the narrows it is about seven-eighths of a mile north to the end of the spit that runs east from the opposite shore. The ends of both spits have been evidently formed by the waves and shore-currents while the lake has had nearly its present level. The higher plain of the Ojibway village, and its extension northward along the greater part of the southeastern spit, were apparently formed similarly, their material being eroded from the shore near Sand Cliff point and carried northwestward, when the lake stood fifteen or twenty feet higher than now. But the low land west of Red lake along its outlet shows that the water here could have such higher elevation only by forming a part of lake Agassiz when that held nearly its highest stage.

THE NORTHERN HALF OF RED LAKE.

From the Ojibway village the south shore of the northern part of the lake trends nearly due east thirteen miles, the first seven miles being a few degrees north of east, and the next six miles due east, or in places a little south of east, ending where two or three unusually tall elms were observed close to the shore. Two slightly projecting points, bearing groves of large white pines, were passed one and a half and three miles east of the village; and one and a half miles east of the second Pine point the white pine forest of the massive ridge on the south extends quite to the shore, taking the place of the deciduous species. The next noteworthy projection in the shore line is nearly five miles farther east, being about two miles beyond where its trend first changes from slightly north to slightly south of east. One and a quarter miles farther on is Poplar point, bearing in its woods about a dozen large poplars, forty to fifty feet high, among smaller trees of ash, elm, basswood, canoe birch, balsam poplar, and willow. This point, guarded from the encroachments of the waves by a wall of boulders, is only five or six rods across, and stands out sharply about the same distance beyond the general outline. Till, with plentiful boulders, the northern base of the morainic highland between the two parts of the lake, forms the shore from the Ojibway village to this point and about a half mile farther east. There it is succeeded by a low area of stratified gravel and sand, which extends three miles, having an elevation of only five to fifteen feet.

Two miles east of Poplar point the shore line turns to the east northeast. One and a half miles beyond this bend a swell of till twenty-five to forty feet high, covered with red and white pines, was seen a half mile south from the lake; and spruce, balsam fir, and tamarack grow along the shore. From these conifers the name Spruce point is given to the broad outward bend of the shore a mile farther east, which, however, bears only deciduous trees. This point and the shore for a mile west and one and a half miles eastward are sandy till, with frequent boulders, having a hight of only five to ten feet adjacent to the lake, but rising here and there in hilly tracts thirty to fifty feet high within a quarter or a half of a mile back from the shore.

Big Sand Bar creek enters the lake from the southeast about two and a half miles east-northeast of Spruce point. It is fifteen to twenty feet wide and has no hay meadow. At its mouth it has deposited a delta of sand and fine gravel, which projects fifteen rods into the lake. About a third part of its pebbles are limestone. A low tract of stratified sand and gravel, with no boulders, borders the lake for three-fourths of a mile west of this creek, and for parts of the way thence three miles east-northeastward to the Little Sand Bar creek; but mainly the shore between these creeks is till with numerous boulders, its hight near the lake being five to fifteen feet, while within a quarter or half of a mile it rises to twenty-five or fifty feet.

Little Sand Bar creek, entering the lake from nearly east, is seven or eight feet wide and a foot deep. Its delta of sand and fine gravel juts out five rods, and the mouth of the creek is at its extreme point. Onward the shore trends north 30° east, and slowly turns to due north at the mouth of Tamarack river. No noteworthy projecting point nor abrupt turn in the shore line was noted in this distance of about four and a half miles, nor in the curve north of the Tamarack river, nor along the north side of the lake for sixteen miles thence westward to Big point. Between Little Sand Bar creek and Tamarack river the land is sand and gravel, with occasional but mostly infrequent boulders, being modified drift near the shore, where the hight is only five to fifteen feet. Not far back from the lake the land rises to thirty or forty feet, and bears frequent groves of red and white pines, which also grow in a few places on the shore. Probably till forms some of these higher tracts.

Near the mouth of the little Sand Bar creek I found a water-worn fragment of lignite, about two inches long, on the beach, the only one noticed in this exploration; it was the charcoal-like kind most commonly found in the drift deposits of all western Minnesota. This fragment and the plentiful limestone pebbles in the till and modified drift about this lake have been brought by currents of the ice-sheet from the northwest. The proportion of limestone pebbles about this east end of Red lake is only one-sixth to one-third, being less than farther west, as near the Agency. About sixty rods northeast from the Little Sand Bar creek a block of buff magnesian limestone, about five feet long, and several of smaller size, lie on the beach; they were doubtless united during their transportation by the ice-sheet.

Tamarack or Swamp river, called Sturgeon or Amenikaning river on Beltrami's map, comes in at the extreme east end of the lake. It is 50 to 100 feet wide near its mouth, and is bordered by shores of alluvial sand only three or four feet high. In the high stage of the lake at the time of this visit its water was set back a considerable distance up the stream.

Mr. Nathan Butler writes of this river and the usual route by it to the Big Fork of Rainy river, as follows:

"The canoe route which I traveled from Red lake to Rainy river is up the Swamp river, which comes into the east end of the north lake from a little south of east. About eighteen miles by river, or ten by land, is a portage on the north side, half a mile above the forks. There is but one place on this river dry enough to land, and that is about half-way up on the south side. The shores on both sides are tamarack swamp, or open meadow, with willows interspersed. The landing is in a tamarack swamp, and the portage is north 85° east, six miles, to the

West branch of the Big Fork river. The first mile is through tamarack swamp, and then four and a half miles through open tamarack and spruce, ten to twelve feet high and about the same distance apart, with the trail worn down into the marsh so that in a wet season it forms a canal in which the canoe can be towed along, with all the baggage in it. The last half mile is higher than any other part or the portage, being about two feet above the level of the water in the river.

"Going down the West branch of the Big Fork river, which is here about twenty feet wide and six feet deep, there is tamarack swamp and meadow on either side, until the stream gradually sinks below the surface enough to drain the land along its banks. Then we find growing along the banks hardwood timber, and a few scattering white pines, which form good ladders to climb and look out over the surrounding country, which is everywhere the same dead level tamarack swamp. It is some twenty-five or thirty miles by the river, and about fifteen or eighteen miles in a straight line, from the portage to the Big Fork river, and the course is nearly or quite due east."*

Within two and a half miles northwestward from Tamarack river the shore bends from a north to a west course, and thence it runs west and west-southwest twenty-two miles to the Wild Rice river. This entire north shore of the northern part of the lake has no salient point. Its only projection is a broad swell, called Big point, that stands out slightly from the general outline about five-sevenths of the way from Tamarack river to Wild Rice river. Nearly all of this shore is swamp, bearing tamaracks, which vary in hight from twenty-five to seventy-five feet. With them are occasionally seen spruce, balsam fir, and arbor-vitæ, while all the slightly higher but still wet tracts bear also small poplars and canoe birches. The surface of this vast swamp is only one to three feet above the lake, from which it is separated by a wave-formed beach of sand, elevated one to three feet above the swamp and covered with rushes, grass, bushes, and trees.

A slight stream, only three feet wide and scarcely flowing, bordered by three or four acres of grassy and bushy swale, enters the lake about five miles west from its east end. Near its mouth and in many other places boulders of granite and gneiss up to six or eight feet in diameter are seen on this shore, indicating that the swamp and margin of the lake lie on till at no great depth. The present position of these boulders is probably attributable to the action of ice freezing to the bottom of the shallow water and pushing them to the shore, as is observable about many lakes throughout the Northwest.

Poplar creek, fifteen to twenty feet wide and two or three feet deep, comes in about nine miles from the east end of the lake; and three miles farther west the Two rivers, each thirty feet wide and three or four feet deep, have their mouths about a third of a mile apart. The lower portions of the Two rivers are bordered by hay meadow, which is separated from the lake by the usual beach ridge of sand and fine gravel. Between the Two rivers, a quarter of a mile back from the lake, and along the shore for a mile eastward, a surface of till rises fifteen to twenty-five feet and is covered by a luxuriant forest of elm, oak, ash, basswood, canoe birch, and other deciduous species, with here and there a tall spiry, dark balsam fir. Another tract of till, having similar hight, but bearing less dense and smaller woods, mostly poplar, borders the lake also at the mouth of Poplar creek, and for a mile thence west. Between these tracts about a half mile of the shore is tamarack swamp.

About fifty rods west from the west one of the Two rivers is the beginning of a "winter road" to the Lake of the Woods, a trail used by the Indians in winter, when the vast swamps of the intervening country are frozen. This trail, as Mr. Roderick McKenzie informed me, crosses the Big river, as it is known to the Indians, twelve miles north of Red lake. At this crossing the stream is twenty-five or thirty feet wide and flows northeastward. Some twenty miles farther north the trail crosses a branch of Big river, and a second branch of the same is crossed about six miles south from where this road reaches the Rainy river eight miles above its mouth. The whole distance from Red lake to the Lake of the Woods by this route is called by the Indians eighty-five miles.

The Big river flows in a general course a few degrees east of north, nearly parallel with the winter road and on its east side, entering Rainy river, according to Mr. McKenzie, thirteen miles from the Lake of the Woods. It appears to be the same stream to which the names Winter Road river and Rapids river have been applied, though these names, probably erroneously, are shown by maps, following Nicollet, to belong to the first and third of three entirely distinct parallel streams. The earlier notes and map of Long's expedition, which are more reliable for that region, indicate instead only one large stream there, which he named the River of Rapids, "so-called from the fine rapids which it presents immediately above its mouth."†

Mr. Nathan Butler has given the following description of this road and the country traversed by it:

"Several rivers come into the Rainy river from the south and southwest, the Black river, three miles below the Big fork, and the Winter Road river, twelve miles above the mouth of the Rainy river or Lake of the Woods, and two or three others between them. There is a winter road, or dog sled trail, leaving the Rainy river at the mouth of the Winter Road river and running about S. 20° W. fifty miles, to the middle of the north shore of the north Red lake. The whole distance is one continuous swamp, tamarack and open, except where the streams have cut down into the ground from six to twelve feet below the surface, thus draining the land on either side for forty or fifty rods. Along the banks of these streams grow poplar, oak, elm, and small red pine timber, but none large enough for lumber. I traveled over this road, or trail, the last week in May, and the frost was out of the ground only about a foot below the surface, or I think we could not have passed over some of the open marshes, as they appeared like what was once floating bog upon a lake, now a bottomless pit. In fact, we waded in mud and moss full of water, ankle deep, from Rainy river to Red lake, except along the banks of the streams that we crossed; and we had to have a brush heap for a bed, to keep us out of the water, every night, excepting

*_Lumberman and Manufacturer_, Dec. 7, 1877.

†_Keating's Narrative_, vol. ii, p. 111.

one when we camped on the bank of a stream. Climbing the tallest trees no sign of dry land or heavy timber could be seen anywhere, nothing but the same endless tamarack swamp. The Indians do not pretend to visit this part of their reservation except when it is frozen. The water in this swamp is level with the water in Red lake around its entire north shore, being separated from it by a ridge of sand thrown up by the ice and water, a rod or two wide and from two to six feet high." *

About four miles west-southwest from the Two rivers, the shore turns for a mile to a course a few degrees more westerly, forming Big point, the farthest land seen on this north shore in the view from its west end at the mouth of Wild Rice river, six miles distant. A tributary stream, ten to fifteen feet wide, entering the lake, as I was informed by Mr. McKenzie, a third of a mile west of this point, is called Big Point creek. Nearly two miles farther west, I observed a small creek, ten feet wide and a foot deep, with a few acres of hay meadow bordering it back of the beach, but only three feet wide and four inches deep on the sand bar at its mouth. This whole distance, about ten miles, from the Two rivers to Wild Rice river, is one continuous tamarack swamp.

Wild Rice river joins the lake at the extreme northwestern portion of this half, where the shore turns in a graceful curve to the south. It is at the line of division between the tamarack swamp, which also continues westward, and the undulating area, probably till, five to fifteen feet high, covered with hardened forest, adjoining the shore for the first mile southward. This is a large stream, forty to fifty feet wide and five to seven feet deep for a distance of at least fifty rods from its mouth. Wild rice grows along its banks for a width of six to ten feet. About a mile southwest from its mouth this river flows through the north end of a shallow lake, said to be nearly a mile long, from north to south, called Wild Rice lake from its rank growth of this useful grain, which supplies a large part of the winter food of the Indians. On the east side of this lake a tract of marsh, destitute of trees, extends to the wooded beach of Red lake, about a mile south of this river.

Farther south an area of gravel and sand, with no boulders, gradually rises to a hight of fifteen or twenty feet. The most southwestern two miles of this shore, extending to the low west point of the narrows, is a beautiful beach of sand and fine gravel, not bordered in front by the rushes and tall reed-grass that generally grow in the edge of the water of this north part of the lake to a distance of ten or fifteen rods from the shore, hiding the beach from the sight of the canoe voyager.

Only a few trees, poplars and elms, and occasional clumps of bushes, with grass, grow on the narrow sand spit, about a mile long and only three to five feet high, which projects due east, forming the north side of the narrows. Its extremity for a length of twenty rods, with a width of one or two rods, is bare sand, only a few inches above the high stage of the lake. On this sand I counted about a hundred and fifty gulls, which rose and circled over us as our canoe rounded the point, entering the south half of the lake. There, too, a fine sand beach, free from rushes and grass, reaches west a long distance. Near this narrows, perhaps at its opposite side on the site of the Ojibway village, there will probably be in future years a summer resort of tourists and sportsmen, attracted hither by the beautiful wide expanses of this double lake, by the fish and fowl of its waters, and the moose, deer and caribou of the surrounding forest.

From the Narrows Around the West Point of the Southern Half of Red Lake to the Agency.

From the West Narrows point the north shore of the south half of Red lake trends only a few degrees south of west for one and a half miles, and thence nearly southwest for three miles, passing the mouths of three small creeks. A prairie of flat sand and gravel, about ten acres in extent and three to six feet high, borders the shore a mile west of the narrows. It bears no trees nor brush, and seems to be naturally unwooded, but it has no ordinary prairie sward, being covered with nodding lyme-grass or wild rye, strawberries, raspberries, very small plants of smooth sumach, and several species of golden-rods and asters. Close west of this is a tract of a few acres of hay meadow, bearing a fine crop of blue-joint grass; and such little patches of meadow, with stacks of hay made by the Indians, were seen in other places westward just back of the beach. After passing about a mile of tamarack swamp, the shore farther west, beginning about three miles west of the narrows, is in part low, slightly undulating till, with frequent boulders, which are almost all gneiss, and granite. About half of the gravel here is limestone. With the tracts of till, bearing poplars, canoe birches, elms, and bur oaks, are other more extensive tracts of tamarack swamp, in portions of which all the trees have died but remain standing, their dead trunks and branches being festooned with mosses.

Starting point, four miles west from the narrows, is so named by the Indians because they gather there for starting in company in canoe trips to the outlet and down the Red Lake river. Here the shore turns to a west-southwest course, which it holds for the next six miles, and thence curves gradually for six miles onward southwest and south to the outlet. All the land bordering this part of the lake is low, being partly tamarack and spruce swamp, while other portions rise slowly to a hight of fifteen or twenty-five feet. These higher portions are apparently till, and bear a heavy growth of hardwood forest. Often a belt of hay meadow, ten to fifty rods wide, intervenes between such tracts and the beach ridge, which is sand and gravel with occasional boulders.

Oak creek, about ten feet wide, comes in some four miles north of the outlet, deriving its name from the occurrence of several large oaks on the beach near its mouth. A marsh, destitute of trees, but with tamarack and spruce swamp beyond it westward, borders the lake thence one and a half miles south-southwest to Last creek, which is of similar small size, being the last tributary passed in approaching the outlet. For a half mile south from Last creek the shore is five to ten feet high, and bears a heavy growth of mixed timber, mostly deciduous species, but including also frequent spruces and balsam firs.

* *Lumberman and Manufacturer*, Dec. 7, 1877.

Marsh with no trees borders the lake for a mile or more from the outlet both to the north and south; but at no great distance back from the shore and river the surface rises a few feet higher in a slightly undulating prairie. An aboriginal mound, about fifteen feet high, is situated on this prairie north of the Red Lake river about a quarter of a mile from the mouth of the lake. The outflowing stream is at first about ten rods wide and one to three feet deep, but is narrowed to six rods within an eighth of a mile, its course for that distance being northwest.

Red Lake river is said to receive no tributary till it reaches the mouth of Thief river, about forty miles distant west-northwest. It has a very meandering course, bordered by marshy land for ten or fifteen miles next to the lake, and thence by slightly higher land with hardwood forest. Two days are required to descend it in canoes to Thief river, and three and a half days to return. It has considerable current, but no rapids excepting within a few miles above the mouth of Thief river. There the bed of the stream is in some places paved with drift boulders and coarse gravel, so that in low stages of water, as Beltrami relates, canoes are relieved of part of their load to protect them from injury.

Low shores of sand and gravel, with no boulders, bearing mostly small poplar woods, but having two groves of large hardwood that perhaps occupy areas of till, begin about a mile south of the outlet and extend some four miles, curving from south to southeast. Then hay meadow, a quarter of a mile wide, borders the lake for the next mile, to the mouth of Sandy river, which comes in at the most southwestern portion of the lake.

The last third of a mile of Sandy river, about thirty-five feet wide and four feet deep, flows east, but the general course from its sources a few miles southeast of Clearwater lake to its mouth is northwest. Many logs of white and red pine have been cut and floated down this stream by the Indians. About a mile west from its mouth is the southeast end of a lake nearly one and a half miles long and a sixth to a third of a mile wide, which is a favorite resort of wild ducks. Mr. McKenzie described it as bordered by marshy and reedy shores, but having a large expanse of clear water, with a maximum depth of seven feet. Its hight is only one or two feet above Red lake, from which its southeast portion is separated by a belt of marsh and beach sand together about a quarter of a mile wide. Its short outlet flows through marsh and hay meadow to the Sandy river.

Till, thinly overlain in some places by stratified gravel and sand and covered with a magnificent hardwood forest, interspersed with occasional groves of white, red and jack pines and scattered spruces and firs, forms the south shore from Sandy river to Little Rock creek, a distance of about six miles. For one and a half miles from Sandy river to Big Rock creek, the trend is east-southeast; then for two and a half miles it is nearly due east. These portions have low shores, not eroded by the lake and consequently strown with only few boulders; but the surface rises southward to thirty or forty feet within a mile. Farther eastward the trend is a few degrees north of east, and the eroded shores usually rise steeply ten to twenty-five or thirty feet, and are at the base, especially about projecting points, bordered by walls of boulders, derived from the till that has been worn away.

Big Rock creek, flowing into the lake from the southeast, is also called Shell creek for Shell lake from which it issues, where it is crossed by the road from Red Lake agency to White Earth. It takes the former name, from two large boulders, each about eight feet in diameter, which lie some five rods apart on the lake shore, one on each side of the mouth of this stream.

About four and a half miles farther east we passed Little Rock point and creek, a quarter of a mile apart so-called because of the beach of many little boulders, one to two feet in diameter, which extends an eighth of a mile each way from the mouth of the creek. A large boulder, some eight feet in diameter, lies on the shore only ten feet east of its mouth, standing up quite alone. An Indian clearing reaches along the shore a third of a mile to the east, comprising more than a hundred acres of fertile cultivated land, with several substantial houses.

Little Rock creek is commonly known as Hay Meadow creek, where it is crossed by the road to White Earth about three miles southwest of Red Lake Agency. It there is bordered by a tract of meadow, and a quarter of a mile northwest from the road it flows through a small lake. It is called Gravel river by Beltrami, who visited and named a series of eight small lakes tributary to it.

Sections of the bank, about twenty-five feet high, adjoining the lake west of this creek, are wholly till of the ordinary type, excepting that an imperfect stratification was observed in the upper five feet; but an eighth of a mile east of the creek, and for three miles onward, the land is stratified sand and fine gravel, and as no boulders are seen along the shore for that distance, it is evident that the underlying till does not there rise to the lake level. Red Water creek, very small, probably named thus in allusion to the bog iron ore of its springs, enters the lake half way between Little Rock creek and the Agency. The trend of the shore, along this distance of about four miles, is nearly due east.

Boulders are again strown plentifully on the beach for a third of a mile next west of the Agency and Pike creek; but the surface, here cleared and cultivated by the Indians, is stratified gravel and sand, yet quite productive, like all the modified drift of western Minnesota, on account of its considerable proportion of limestone. A section freshly exposed, a quarter of a mile west from the mouth of Pike creek was dark soil, one foot; levelly stratified sand and fine gravel, five feet; and ordinary yellowish till or boulder-clay, enclosing many rock fragments and occasional large boulders, twenty feet, to the level of the lake. Five feet below the top of the till, it contains a layer a foot thick, somewhat darker and moister than its other portions. The boulders here and about all the lake are, as before noted, nearly all Archean gneiss and granite, micaceous and hornblendic, with scarcely any mica schist or other schists. Occasionally a dark or greenish trappeau boulder was found, but no slate, sandstone nor conglomerate, and nothing that seemed referable to the Keweenawan series of lake Superior.

Northern Part of the Route to Cass Lake.

The route from the Agency to Cass and Leech lakes was examined for a distance of about six miles, to its lower crossing of Pike creek. Nearly a mile east of the Agency it diverges from the west-to-east road leading to the chief's village, and passes southeastward. After leaving the level plain of sand and fine gravel, about three-fourths of a mile wide, which borders the lake, it pursues a crooked course through an area of very irregular knolls, composed similarly of sand and gravel, but deposited in short ridges, mounds and hillocks, twenty to forty feet high. Many of the intervening depressions are occupied by small tamarack swamps. The trend of the ridges and swamps is more frequently from east to west than in other directions, but this is not usually conspicuous along the course of the road. Occasional boulders were seen on the surface of many of these knolls, but nowhere in such numbers as are common on morainic tracts, and no deposits of till or boulder-clay were found. Such uneven surface extends two or three miles, and its northern and southern boundaries are each a valley-like depression that runs somewhat deviously from east to west. Beyond this belt the road passes over a slightly undulating plain of gravel and sand, with the higher parts five to ten feet above the depressions, excepting here and there steep-sided hollows, ten to twenty-five feet deep, often enclosed on all sides with no outlet. The northern border of the area of knolls has an elevation of about fifty feet above Red lake, or 1,225 feet, approximately, above the sea level. Thence the elevation rises slowly southeastward, so that the plain in the vicinity of the lower crossing of Pike creek is about 1,325 feet, and the stream 1,300 feet, above the sea. Farther to the southeast deposits of sand and gravel, partly in the knolls and ridges, and partly in nearly flat tracts, are said to occupy most of the country to Cass and Leech lakes. The forest on the area examined consists chiefly of poplars and bur oaks, and jack and red pines, but contains only rare white pines. No beach formations nor other distinct evidence of lake action were observed.

These gravel knolls were doubtless formed by short glacial streams, flowing down from the border of the ice-sheet in its recession, which on this district was probably from southwest to northeast or east. Where the belt was crossed by Norwood in 1848, apparently two or three miles farther east, it consists of massive and prolonged gravel ridges or kames, described by him as follows:

"Between three and five miles south of Red lake, we passed three high barren ridges, and one low one, with very steep sides, and separated by narrow valleys. These ridges bear nearly northeast and southwest, and are composed of sand, intermingled with gravel and pebbles, derived from both crystalline and sedimentary rocks. * * * North of the ridges is a valley about three-fourths of a mile wide, thickly covered with small cypress [arbor-vitæ]. The most northerly ridge (the one next to Red lake) rises only eleven feet above the valley, and is very little higher than the land near the lake shores. The next one south of it is fifty-three feet above the intervening valley; and the third one is sixty-six feet above a small stream which flows in the valley between it and the second one; while the summit of the fourth, or most southerly one, is eighty-two feet above the bottom of the valley between it and the third. These ridges are not timbered; only a little coarse grass and a few scattering bushes grow on them. The valleys support a small growth of such timber as was seen on the rolling lands immediately south of them."*

Sections on Pike Creek near the Agency.

Two interesting sections of the drift were noted in the banks of Pike creek near the Agency (figure 2, plate M). East of the bridge on the main road excavations show soil, one foot; a sandy and gravelly unlaminated deposit, much like the upper till of New England, three to five feet, enclosing numerous granite boulders up to five feet in diameter, and yielding to my search one striated rock fragment about four inches long; then obliquely laminated sand and gravel, chiefly sand, but having layers of gravel in which stones are rarely found as large as one foot in diameter, twenty feet, reaching to the level of the stream. About thirty rods south-southeast from this locality, the surface deposit at the mill is sandy and gravelly till, four to seven feet thick, enclosing plentiful rock fragments of small sizes and occasional boulders up to seven or eight feet in diameter, but mostly showing some indistinct lamination; beneath which are sand and gravel, ten to twenty feet thick, to the pond and stream below, horizontally stratified, but with many of the layers obliquely laminated, containing no boulders. These observations indicate that the stratified gravel and sand of this plain bordering the south shore of Red lake were deposited close to the retreating ice-sheet or even in some places beneath its edge, from which coarser and unassorted drift, including large boulders, as in the sections noted, were laid down upon the stratified beds.

Observations between Red Lake and White Earth.

The distance in a direct line from the Red Lake Agency southwest to White Earth is about sixty-seven miles. By the course of the road it is called eighty miles. Five or six houses, all but one inhabited by Ojibways, are scattered at intervals of many miles apart, along this distance. The weekly mail from and to Red Lake, at the time of my visit, was carried by an Indian, who usually made the journey afoot both ways in five days. For myself three days of hard travel afoot were required to reach Red Lake from Fosston, coming upon this road at Mr. Knud Thompson's; and four day's walking took me out to White Earth. Though consuming so much time, this was almost as expeditious and comfortable as to travel by wagon, because of the roughness and bad condition of the road.

The nearly level plain of modified drift on the south side of Red lake extends one and a half miles, and is succeeded southward by a belt, also about one and a half miles wide, of isolated small plateaus of gravel and

*Owen's Report of a Geological Survey of Wisconsin, Iowa, and Minnesota, 1852, p. 326.

sand, divided by steep-sided depressions, twenty-five to forty feet deep, some of which contain small lakes and tamarack swamps. Boulders are absent or very rare on the plain, but are frequent, with much coarse gravel, on the plateaus, so that portions of the latter resemble till.

Little Rock or Hay Meadow creek, there five feet wide and a foot deep, forms the boundary between this plateau tract and an area of moderately undulating till, over which the road lies for a distance of about four miles. This area has much large white pine. In its depressions are occasional lakes, from one of which, named Shell lake, a third of a mile wide, lying close east of this road, the Big Rock or Shell creek flows northwest, having a width of ten feet and depth of one foot.

A beach ridge of sand, probably marking the highest level of lake Agassiz, is crossed by the road in the northeast corner of sec. 21, T. 150–35, about two miles beyond Big Rock creek. Its elevation above Red lake is approximately fifty feet, or about 1,220 feet above the sea. A grove of red pines grows on this sand, but the till on each side bears white pines.

Knolls of gravel and sand begin three-fourths of a mile south of the beach and occupy a belt about two miles wide, reaching west-southwest to the Sandy river. Their surface consists of many hills and short ridges, having no prevailing parallelism in their trends, with crests ten to twenty feet above the enclosed hollows. The material is mostly sand, with some gravel, irregularly stratified, and enclosing frequent boulders. A descent of about 100 feet is made in a third of a mile to Sandy river, which at the bridge on this road is about thirty feet above Red lake, or 1,200 feet above the sea. It here flows northwest and has a width of fifteen to twenty feet and depth of about two feet. On its southwest side is a flat-topped terrace of sand and gravel, with no boulders, having a width of about an eighth of a mile and extending within sight at least a half mile along the stream, above which its hight is about sixty feet. For nearly a mile onward the surface is in long kame-like ridges and plateaus of sand and fine gravel with no boulders, trending from east to west, with crests gracefully rounded or flat and from a few rods to an eighth of a mile wide, elevated ten to thirty feet above the depressions and sixty to eighty feet above the river. In one of its larger hollows a lakelet some fifty rods long was seen a quarter of a mile west of the road. This area is wooded with red pines. Probably these kame accumulations and the knolls on the other side of the river are together the continuation of the belt of similar deposits crossed by me a few miles southeast of the Red Lake Agency and by Norwood still farther east.

Beyond this tract of eskers and kames, the road passes over moderately undulating or rolling till, with many boulders, about three and a half miles to the crossing of Clearwater river, one and a half miles west of Clearwater lake. This formation also continues nearly ten miles farther, terminating at the south end and outlet of Four-legged lake. Its crests are mostly ten to thirty feet above the depressions and occasional lakes, to which the descent is often by somewhat steep slopes; but generally this area lacks the rough contour characteristic of marginal moraines.

Clearwater lake has a partially irregular outline, two and a half miles long from northwest to southeast, with a maximum width of about one mile. It is surrounded by a rolling surface of till with plentiful boulders, which rises, often by the steep bluffs due to erosion, twenty to fifty feet above the lake, being highest on the east side. The outlet is at the end of a narrow western bay, where a dam ten rods long raises the lake fifteen feet for supplying water during the season of log-driving. Thirty to forty million feet of white and red pine are cut yearly on the Clearwater river and its tributaries above this lake, and are floated by the Clearwater and Red lake rivers to Red Lake Falls, Crookston, and Grand Forks, in which towns they are sawn into lumber. The elevation of Clearwater lake is approximately 1,225 feet above sea level. Its maximum depth, as reported by the lumbermen, is about fifty feet. Below this lake the Clearwater river flows about forty miles in a west-northwest course, nearly parallel with the Red Lake river; and beyond this portion it flows southward and westward to join the latter river at Red Lake Falls. It is bordered by moderately rolling till, as at the lake, for several miles; thence, entering the area that was covered by lake Agassiz, it runs a long distance meanderingly through marshes and hay meadows only a few feet above the stream and subject to occasional overflows from it.

Four-legged lake, bearing the name of an Ojibway who lived beside it, lies close east of the road. Its outlet flows westward to Ruffee creek, called by the Ojibways Four-legged creek, which joins the Clearwater river ten or twelve miles below Clearwater lake. It has a very irregular form, comprising an area of nearly two square miles, with low shores of moderately undulating till, covered on the east and southeast by a forest of white pine. This lake is about 200 feet above Clearwater lake, or 1,425 feet above the sea.

Small knolls of sand and gravel, having a very uneven surface, with crests ten to twenty feet above the hollows, occupy the next one and a half miles south of Four-legged lake. Then the road for two miles traverses a morainic belt of steep hillocks and small ridges, twenty to thirty feet high, composed mostly of sandy and gravelly till with many boulders of all sizes up to eight or ten feet in diameter. This is succeeded southward by a width of nearly two miles of moderately undulating till; and the same formation, in large part overlain thinly by nearly level deposits of gravel and sand, covered with jack pine, reaches thence about six miles southward to the upper crossing of the Clearwater river at Mr. T. B. Walker's "depot camp."

The Clearwater river, flowing easterly at this crossing, has eroded a valley about fifty feet deep and from an eight to a half of a mile wide. A dam, about thirty rods long, is built here for logging purposes, having a head of ten or twelve feet. Excavations at each end of this dam show sand, ten feet or more in thickness, overlain by about thirty feet of till. The same layer of sand probably extends a mile and a quarter south, where Knud Thompson's well in the south edge of the S. W. ¼ sec. 36, T. 147–38, was dug to a depth of 106 feet, finding the following order of deposits: dark soil, one foot; yellowish till, requiring to be picked, ten feet; dark bluish till, which was also picked, twenty feet; yellow sand, twenty feet; again blue till, picked, forty feet; and

FIG. 1. TEMPORARY LABORATORY, CAMP OVERDONE, HOODOO POINT.

FIG. 2. THE FIELD OUTFIT ON THE PLAINS. (p. 167.)

yellow gravel, fifteen feet to bed-rock, thought by the workmen to be limestone. No supply of water was found. The elevation of the surface at Mr. Thompson's is approximately 1,500 feet above the sea; and of the Clearwater river at the "depot camp," 1,400 feet, being thus nearly 200 feet above its lower crossing. Between these points the river flows in a long detour to the east and north, probably thirty miles.

Moderately undulating or rolling till, bearing occasional groves of large white pines, stretches from the Clearwater river and Thompson's ten miles southward to the Wild Rice river. Thirty or forty years ago the greater part of this area was occupied by a stately white pine forest, which has been mostly destroyed by fires, leaving the land bare or covered with bushes and small poplars.

Between two and three miles north of the Wild Rice river the road crosses a somewhat morainic tract, with very plentiful boulders. Its elevations, trending mostly from east to west, rise some sixty feet above that stream, and twenty-five to forty feet above the average of adjoining areas. A few miles farther east a massive moraine of steep and irregularly grouped hills, 100 to 150 feet high, was seen along the east side of Mosquito brook for about three miles northeasterly from the north end of Lower Rice lake. Similarly conspicuous morainic hills, forming a belt, three miles or more in width, also border the western part of the Upper Rice lake.

The Wild Rice river at this crossing, about a mile west from the north end of the Lower Rice lake, is five to seven rods wide and six to eighteen inches deep. It is only ten or fifteen feet below the general level of the region, having no noteworthy valley. Numerous boulders up to seven feet in diameter, mostly granitic but including rarely one of limestone, lie in the channel. Its elevation and that of Lower Rice lake are approximately 1,450 feet above the sea. This lake, through which the river flows, is four miles long from south to north and about a mile wide, varying in depth from one to five feet, and filled throughout nearly its entire area with a luxuriant growth of wild rice; so that its appearance in summer, when seen from a distance, is that of a grassy marsh. Nearly all of this valuable grain that is gathered for food by the Indians of the White Earth reservation is obtained here.

Southwest of the Wild Rice river, the road for the next seven miles passes over a tract of modified drift, consisting of flat or slightly undulating sand and fine gravel, with the higher portions only five or ten feet above the depressions, to which the descent is by long and gentle slopes. Its hight above the river and the Lower Rice lake is twenty to forty feet. Part of this tract is wooded with small jack pines, but fully half of it is prairie. Its width reaches at least one or two miles on each side of the road, as far as the view extends.

About two miles southwest of Mountain lake and creek, and thence onward four miles to the Twin lakes, the morainic belt on the east approaches nearly or quite to the road, which there crosses low knolls and eskers of sand and coarse gravel, with crests ten to twenty-five feet above the depressions, mostly trending from north to south, either prairie or sparingly wooded. The morainic hills, composed of till with many boulders, and having the usual very rough contour, rise to hights of 100 to 200 feet above the road within one to two miles east, bearing small hardwood and occasional pines. Many portions of this range were formerly covered with a valuable forest of white pine, now mostly burned, but still remaining on its crest east of the Twin lakes. Another tract of large white pine woods, probably marking a low belt of morainic till fifty to seventy-five feet above the Twin lakes, was seen on their west side and along a distance of several miles northward.

The Twin lakes, Heron lake, and White Earth lake are approximately 1,500 feet above the sea, being about 100 feet below the White Earth Agency. Between the Twin lakes the road lies on a tract of moderately undulating sand and gravel ten to twenty feet above these lakes, west to the outlet from the south to the north lake, a stream four to six feet wide and three to six inches deep. Within the next half mile west the road runs along the south side of a kame of sand and fine gravel, twenty-five to forty feet high, and esker-like deposits extend about half a mile farther southwest. Next are two miles of till with abundant boulders, in low morainic accumulations, the contour being a diversified assemblage of knolls, hillocks, and short ridges, more frequently trending from east to west than otherwise, but rising to elevations only ten to fifty feet above the intervening hollows and plentiful lakes.

Thence to the southwest end of the South Heron lake, a distance of about four miles, the surface continues similarly uneven but with no prevailing trend, and the material is sand and coarse gravel in eskers, containing waterworn cobbles up to eight or twelve inches in diameter but no larger boulders. These deposits were once partly covered with red and white pines, of which here and there a dead trunk remains standing. At present considerable tracts are wholly destitute of timber, while others bear small poplars.

From South Heron lake to the White Earth Agency the surface is till. For two miles, to White Earth lake, it has a morainic contour, with elevations ten to forty feet above the hollows and lakes, but these show no noteworthy parallelism in their trends. The forest has no pines, but consists of a heavy growth of deciduous species, including bur and black oaks, elm, hackberry, basswood, canoe birch, and poplars. Between the mouth of White Earth lake and the Agency, a distance of six miles, the same hardwood forest alternates with areas of prairie, and the surface is moulded in smooth swells and massive, broadly rounded, low hills, twenty-five to fifty feet above the abundant lakelets, which are of all sizes from a few rods to a mile or more in length. The till here seems more clayey, and the soil more fertile than in any portion of the country about Red lake, or thence southward along this road to the vicinity of White Earth lake.

The field outfit of the survey on the plains is shown in figure 2, plate VV, a photograph taken before starting in the morning.

CHAPTER VIII.

THE GEOLOGY OF ITASCA COUNTY.*

BY U. S. GRANT.

Situation and area. Itasca county (plate 65) is the central one in the tier of seven counties on the northern side of the state, bordering on Canadian territory. The county is approximately rectangular in outline, the greatest length (north and south) being 116 miles, and the width sixty-two miles. The area was formerly 5,878.88 square miles, or 3,762,483.01 acres, of which 5,662.27 square miles (3,624,041.22 acres) are land, and 216.31 square miles (138,438.89 acres) are water.† Since the foregoing figures were compiled (by Hon. H. H. Young, previous to 1884), 256 square miles have been taken from Cass county and added to Itasca county, making *the present area of Itasca county* 6,134.88 square miles. The area thus added is the triangle bounded on the northeast by the Mississippi river, on the south by the south line of T. 53 N., and on the west by the west line of R. 27 W. Itasca county thus becomes, with one exception (St. Louis, 6,611.75 square miles), the largest county in Minnesota.

SURFACE FEATURES.

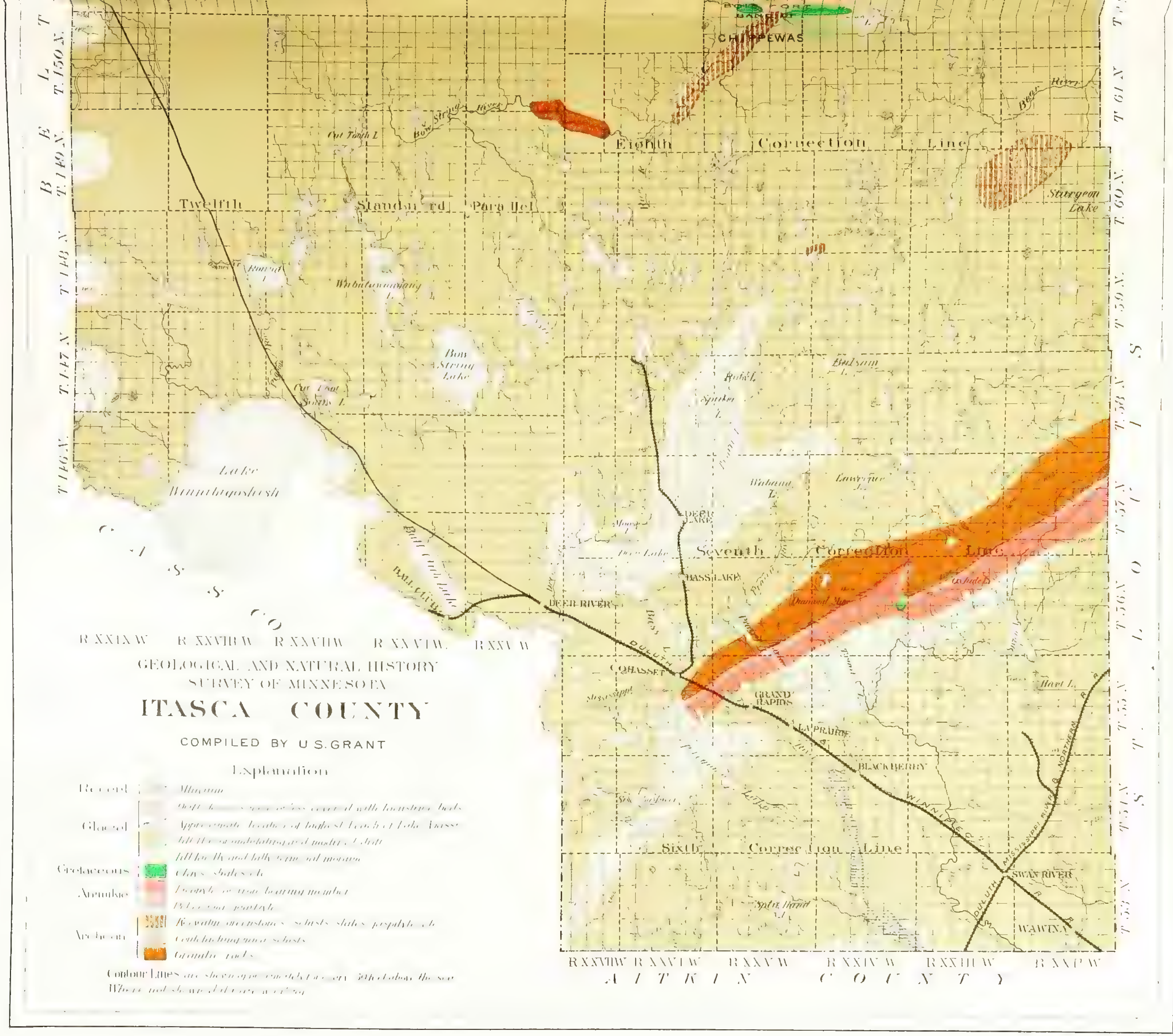
Natural drainage. Itasca and St. Louis counties are the only two counties which lie in the three great drainage basins of the state, *i. e.*, the basins of (1) Hudson bay, (2) The gulf of St. Lawrence, and, (3) The gulf of Mexico.

(1). Hudson Bay basin. About two-thirds of the area of Itasca county is drained eventually into Hudson bay, largely through the Rainy river, which runs westward along the northern side of the county. The southern limit of this drainage, or the

*The material for the chapter on this county has been collected from the following sources: Field work of H. V. WINCHELL in 1887 and his report (*Sixteenth Annual Report*, pp. 393–478); field work of N. H. WINCHELL in 1888 and his report (*Eighteenth Annual Report*, pp. 13–19); field work of WARREN UPHAM in 1893 and his report (*Twenty-second Annual Report*, pp. 18–66); field work of G. E. CULVER in 1893 and his report (*Twenty-second Annual Report*, pp. 97–114); field work of H. V. WINCHELL and U. S. GRANT in 1894 and their report (*Twenty-third Annual Report*, pp. 36–105); report on the geology of the Rainy lake region, by A. C. LAWSON (*Geol. Survey of Canada*, new series, vol. iii, part i, pp. 1F–182F.) We are also indebted to HON. S. P. SNIDER and MR. R. M. BENNETT, of Minneapolis, for certain information concerning the Mesabi iron range.

This chapter is necessarily incomplete for two reasons: *First*—A large part of the county is unsettled and has not been visited by parties of the survey. Only part of the southern third of the county has been examined in detail, and for our knowledge of the rest of the county, except for the district around Rainy lake, we are principally dependent on reports of canoe trips along the Big Fork and Little Fork rivers. *Second*—The writer of this chapter has seen only a small portion of the county,—in fact, the only part of it which he has visited is a limited area around Rainy lake, in the extreme northeastern part of the county. Thus the chapter is, of necessity, largely a compilation. No attempt is made to indicate the sources for each item of information; the general acknowledgment to the sources given above is considered sufficient.

†These figures are taken from p. 115, vol. i, of the final report of this survey. Since the publication of that volume a number of the unsurveyed townships have been surveyed, and it seems that a careful determination of the land and water areas in these townships would change the figures given above. The water area (216.31 square miles) certainly seems too small, especially when compared with the adjoining county on the east (St. Louis), whose water area is given as 774.49 square miles exclusive of any part of lake Superior.


GEOLOGICAL AND NATURAL HISTORY
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ITASCA COUNTY
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Twelfth Standard Parallel
Eighth Correction Line
Seventh Correction Line
Sixth Correction Line
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Bow String Lake
Sturgeon Lake
CHIPPEWAS
DEER RIVER
COHASSET
GRAND RAPIDS
LA PRAIRIE
BLACKBERRY
SWAN RIVER
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DEER LAKE
BASS LAKE
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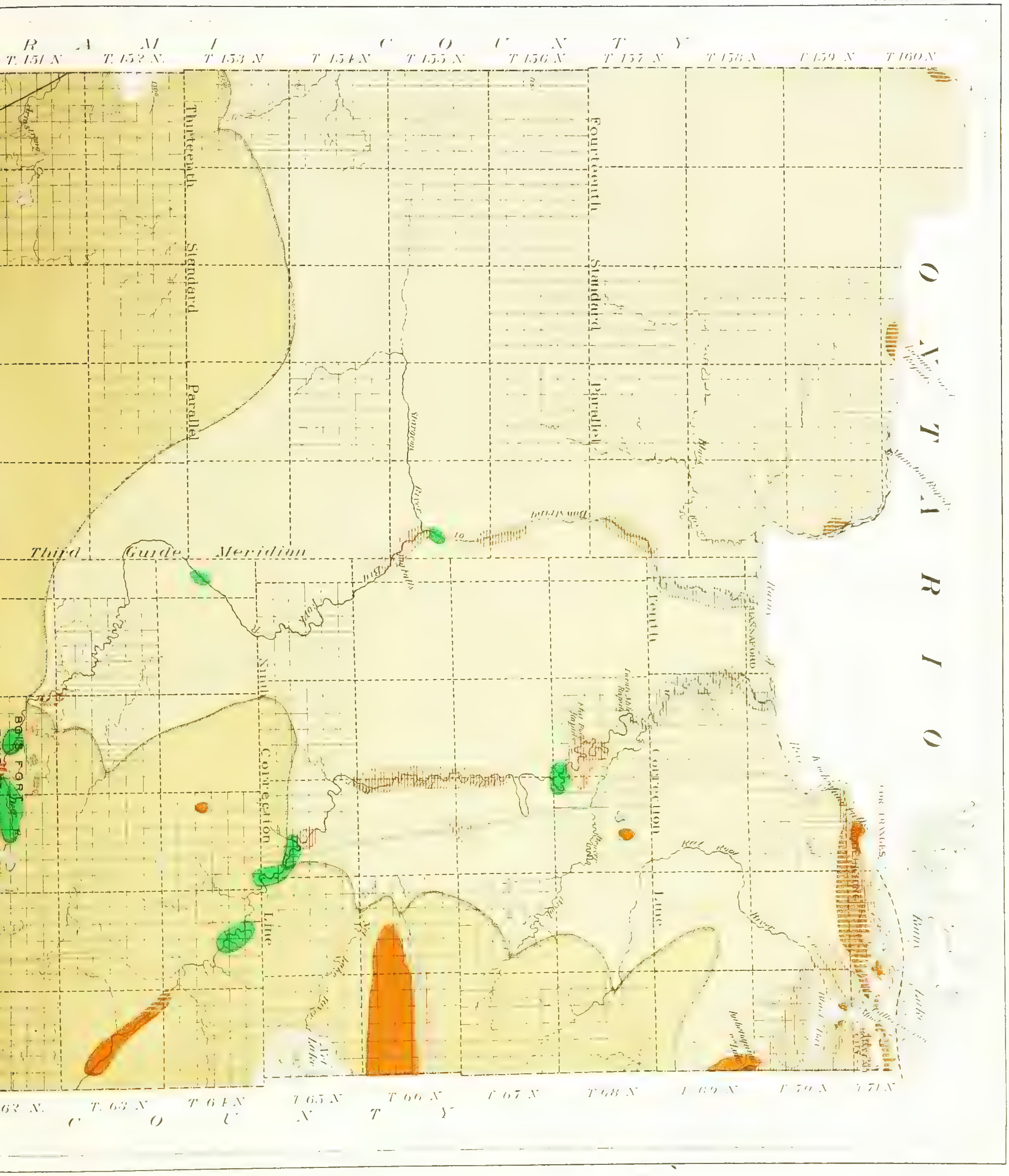
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T. 159 N
T. 160 N
Thirteenth Standard Parallel
Fourteenth Standard Parallel
Third Guide Meridian
Ninth Correction Line
Tenth Correction Line
O N T A R I O
BOIS FORT
T. 63 N
T. 64 N
T. 65 N
T. 66 N
T. 67 N
T. 68 N
T. 69 N
T. 70 N
T. 71 N
C O U N T Y

divide between waters flowing into Hudson bay and those flowing into the gulf of Mexico, has approximately the following course: On the west it enters the county in T. 148–29, and runs southeast, keeping south of Bowstring lake, into T. 146–25, where it turns northeast and continues in this direction to the southern part of T. 60–24, thence running eastward to the eastern edge of the county. The lakes and streams to the north of this divide, with the exception noted below, empty into the Rainy river, principally through the Big Fork (Bowstring) and Little Fork rivers. The former flows northward through the central part of the northern half of the county and the latter flows northwest through the northeastern quarter of the county. The only portion of the northern two-thirds of Itasca county which is not drained by the Rainy river is a comparatively small district lying in the central part of the western side of the county. This area, comprising about 300 square miles, drains westward into Red lake, whose waters eventually find their way to Hudson bay.

(2). *Gulf of St. Lawrence basin.* The part of the county which lies in this basin is very insignificant. A small area, not exceeding forty square miles, in the southeastern corner of the county, is drained by a branch of the Floodwood river, which is a tributary of the St. Louis. This small area is largely included in T. 53–22.

(3). *Gulf of Mexico basin.* That part of the county lying south of the divide mentioned under the Hudson Bay basin is, with the exception of the small area belonging to the gulf of St. Lawrence basin, drained by the Mississippi river into the gulf of Mexico. The principal tributaries of this river in Itasca county are the Prairie and Swan rivers. About one-third of the area of the county belongs in this drainage basin.

In general, it may be stated that Itasca county is poorly drained. This is evinced by the larger number of lakes and swamps in the southern part of the county, and by the extensive swampy areas in the northern part.

(4). *Lakes.* The southern third of Itasca county contains numerous lakes and ponds of all sizes from those an acre or less in extent to those of several square miles of surface area. The majority of these lakes are in the drainage basin of the Mississippi. They are scattered in the vicinity of Grand Rapids, the county seat, but are more especially numerous in the district ten to thirty miles north of this town. Many of these lakes, especially the smaller ones, have no surface outlets. The northern half of the county contains practically no lakes, but Rainy lake borders on the northeastern corner of the county. The two largest lakes lying entirely within the county are Bowstring lake, containing about twenty-three square miles, and Pokegama lake, containing about ten square miles. Lake Winnibigoshish,* lying near the southwestern corner of the county and partly contained in Cass county, is a comparatively shallow body of water some fifty miles in area. Net lake is on the

*See p. 57 of this volume.

eastern side of the county and contains about eleven square miles. Rainy lake is by far the largest lake bordering on Itasca county. The surface of this lake, inclusive of islands, has been computed to include 344 square miles, its greatest known depth is 110 feet, and the average depth is not far from forty-seven feet. Only a small part of its surface lies in Itasca county.

(5). Importance of rivers and lakes. It is only within the last few years that the southern part of the county has been reached by railroads, and even now the area traversed by railroads and wagon roads is only a small part of the whole. The Mississippi and Rainy rivers are large enough to admit of the use of steamboats, and the latter river is regularly supplied with boats running from the Canadian Pacific railroad at Rat Portage, at the north end of the Lake of the Woods, to Koochiching, where a fall (see plate O, figure 2) in the river prevents further navigation, but above this fall boats ply on the waters of Rainy lake. Before the advent of rail and wagon roads, in all the county, and now in a large part of it, almost the only means of travel in the summer season was by canoe through the various lakes and along the streams. The canoe routes along the Big Fork and Little Fork rivers offer at present almost the only access to the interior of the northern half of the county. In the winter season considerable traveling is done on "winter roads," which on account of the lack of improvement and the large swampy areas, are frequently impassable during the summer months.

Topography. The surface of Itasca county is comparatively level and there are no very prominent elevations—no districts which approach at all towards the mountaneous—but hills, which rise fifty to seventy-five feet above the surrounding country, are not uncommon, and occasionally they rise to three or four times fifty feet. We may compare the surface to a plain whose surface, it is true, contains slight inequalities or undulations. This plain slopes very gently in two directions from a line which is the divide between the waters flowing into Hudson bay and those flowing into the gulf of Mexico. (See page 167). On the south of this line the plain slopes south and southwest to the Mississippi river, and on the north the slope is north to the Rainy river. This line, however, only divides the plain into two areas of different slope, but does not divide it into two areas which are topographically distinct. The plain is, nevertheless, capable of division into two districts topographically distinct, in one of which the surface of the plain is undulating, and in the other it is more nearly a true plain. The first of these districts may be called the *drift district* and the second the *lake-bed district*. The dividing line between the two districts is the shore line of the glacial lake Agassiz, whose course is shown on the map (plate 65). The country lying south and east of this shore line belongs to the first district, and that lying north and west to the second. There is another

very small topographic district, quite distinct from the two others, in the extreme northeastern corner of the county. This is called the *rocky lake district.*

(1). Drift district. This district is so called from the fact that its topography is almost entirely conditioned by drift deposits. In only a few places do the underlying rocks appear at the surface. While the actual elevation of some parts of the county, notably the ridge just to the north of the Mesabi iron-bearing rocks in T. 57–23, and probably that lying southwest of Pokegama lake, is due to elevations of the rock surface underlying the drift, still the actual *form* of the present surface is conditioned by the drift which covers, sometimes to a thickness of many feet, the underlying rock surface. Thus the present surface is, in its form, due to the drift deposits, though the actual elevation of the surface is sometimes dependent on the altitude of the rock surface beneath the drift. As the surface is thus so similar to that of many other counties of the state, which have already been described, it will not be necessary to speak of it in detail. In brief, the surface of this part of Itasca county is moderately undulating, with some areas which are knolly or hilly, and others—often quite large areas—which are nearly level. The lakes and swamps lie in the lower parts of the nearly level and undulating districts, while in the hilly districts they occupy the small depressions between the hills.

The most pronounced elevations in the county are the two ridges spoken of above. The first of these is about four miles in length and runs west-southwest from the south end of Pokegama lake. The ridge lies in secs. 22, 23, 27, 28, and 29 of T. 54–26, and its highest point is 1,617 feet above the sea, or nearly 350 feet above Pokegama lake. The other ridge lies along the north side of the Mesabi iron-bearing rocks and reaches an altitude of over 1,650 feet in the northeastern part of T. 57–23. This is the highest known point in the county, but considerable higher altitudes are reached by the same ridge (the Giant's range) to the east in St. Louis county. There are other hilly districts which will be mentioned under the moraines of the county.

The level or approximately level areas are, at least when their extent is considered, as noticeable as the hilly areas. As has been stated above, the surface is largely a plain with little differences in elevation. This fact is brought out clearly on comparing the elevations along the line of the Duluth and Winnipeg railroad from Wawina, in the southeastern corner of the county, to the crossing of Downes creek west of Round lake. From Wawina, which is in the drainage basin of the gulf of St. Lawrence, the road passes over the divide between this basin and that of the gulf of Mexico, touches the Mississippi river at several points, and then passes into the basin of Hudson bay. Thus, in this distance of sixty-six and a half miles the road runs in three continental drainage basins, but its extreme altitudes are 1,268 and 1,350 feet above the sea, or a difference of only eighty-two feet. Northwest of

Downes creek the road reaches an altitude of 1,442 feet along the ridge which separates the waters flowing into the Big Fork (Bowstring) river from those flowing into Red lake, but this divide is only 174 feet above Wawina, the lowest point of the railroad in the county. Another striking instance of the general flatness of parts of the county is shown in the swamps and muskegs, some of which reach a dimension of many square miles. One of these level areas exists in the vicinity of Swan river station, especially to the east of this point.

(2). Lake-bed district. This includes that part of the county north of the shore line of the glacial lake Agassiz, except the area directly adjacent to Rainy lake. In general surface form this area was formerly quite similar to the drift district of the county, but since the ice retreated from the northern part of the county it has been considerably modified by deposits in the bed of the glacial lake Agassiz. These deposits have covered up and obliterated in part the ancient drift surface, so that the land is now very flat, having a slope toward the north which is too small to allow good drainage. As a consequence this part of the county contains extensive swampy areas, and it is usually only along the banks of the streams, which flow in sinuous channels five to forty feet below the level surface, that much dry land is found. In places the rivers have cut down through the veneer of lake deposits into the drift and occasionally to the underlying rock.

(3). Rocky lake district. As already stated the part of the county included in this district is only the immediate vicinity of Rainy lake. Here are low rounded bosses of rock, alternating with water and swamp areas. Very little drift is found and the soil is usually quite thin and frequently lacking altogether. This type of topography reaches an extensive development toward the east in the northern part of St. Louis, Lake and Cook counties and will be mentioned more fully in the descriptions of those counties, and also in the appendix to this chapter.

ELEVATIONS.

The average elevation of Itasca county has been estimated by Mr. Warren Upham at about 1,280 feet above sea level. Below are given the elevations of a number of points:

Duluth and Winnipeg railroad.

	Miles from Duluth.	Feet above sea level.
Wawina,	69.8	1,268
Swan River station (crossing of D. M. R. and N. R. R.),	74.4	1,293
Summit, in deep cut, 900 feet long; natural surface, 1,333; grade,	75.2	1,303
Swan River, bed, 1,257; water, 1,264; high water (1888), 1,272; grade,	78.7	1,276
Blackberry,	85.6	1,300
Blackberry brook, bed, 1,271; grade,	86.1	1,298
Summit, cutting 5 feet; grade,	88.0	1,299
Prairie river, bed, 1,244; water, 1,246; grade,	90.5	1,283
La Prairie,	91.2	1,283
Grand Rapids,	93.8	1,287
Pokegama falls, Mississippi river above the dam, bed, 1,269; water, 1,276; grade,	96.4	1,285
Summit, in deep cut, 1,000 feet long; natural surface, 1,323; grade,	97.3	1,297
Bass brook, bed, 1,268; water, 1,275; grade,	98.0	1,285
Cohasset,	98.3	1,284
Summit, cutting 6 feet; grade,	101.9	1,312

	Miles from Duluth.	Feet above sea level.
Deer river, bed, 1,271; grade,	107.0	1,281
Deer River station,*	108.5	1,291
Summit, cutting 6 feet; grade,	111.1	1,322
Stream, bed, 1,281; grade,	115.5	1,296
Summit, cutting 3 feet; grade,	116.6	1,311
Stream, bed, 1,278; grade,	118.2	1,291
Summit, cutting 3 feet; grade,	121.6	1,317
Outlet of Cut Foot Sioux lake, water level with lake Winnibigoshish, 1,292;† grade,	125.4	1,299
Summit, cutting 9 feet; grade,	128.0	1,314
Pigeon river, bed, 1,301; grade (not at bridge),	130.0	1,310
Pigeon river, bed, 1,306; water 1,308; grade,	130.9	1,313
Summit, natural surface and grade,	134.4	1,350
Downes creek, bed, 1,317; grade,	136.2	1,339
Summit, natural surface and grade,	143.7	1,383
Creek, bed 1,363; grade,	144.7	1,372
Summit, cutting nearly 20 feet; grade,	150.7	1,442
McMillan creek, bed, 1,359; grade,	155.1	1,388
Summit, cutting, 5 feet; grade,	155.4	1,391
Armstrong creek, bed, 1,341; grade,‡	157.1	1,365

Duluth, Mississippi River and Northern railway.

	Miles from Mississippi.	Feet above sea level.
Mississippi, southern terminus of railroad,	0.0	1,242
Swan river, water, 1,226; grade,	0.5	1,241
Highest level between the two crossings of Swan river, natural surface, 1,276; grade,	2.1 to 3	1,271
Swan river, water, 1,252; grade,	3.5	1,261
Swan River station (crossing of Duluth and Winnipeg railroad); grade,	6.7	1,293
South side of S. E. ¼ sec. 29, T. 54-23, creek, bed 1,308; grade,	10.0	1,315
N. part of sec. 16, T. 54-22; grade,	12.8	1,418
S. W. ¼ sec. 35, T. 55-22, natural surface, 1,466; grade,	15.7	1,456
Creek, bed 1,391; grade,	17.2	1,405
Creek, bed 1,360; grade,	18.7	1,369
Creek, bed 1,350; grade,	19.3	1,366
Creek, bed 1,338; grade,	19.9	1,345
Creek, bed 1,336; grade,§	21.0	1,347

Mississippi river.

	Feet above sea level.
At southwest corner of Itasca county,	1,299
Lake Winnibigoshish, also Little Winnibigoshish lake, formerly	1,290-1,293
Lake Winnibigoshish, as raised by dam of reservoir system,¶	1,298
Mississippi river at head and foot of small rapids three miles below Little Winnibigoshish lake,	1,288-1,287
At mouth of Leech Lake river,	1,279
At White Oak point,	1,276
At mouth of Vermilion river,	1,273
At outlet of Pokegama lake, formerly	1,270
At head of Pokegama falls, formerly	1,269
Same, as raised by dam,	1,275
At foot of Pokegama falls, 900 feet from the last,	1,254
At head of Grand Rapids, one-third mile from the last,	1,248
At mouth of Split Hand river,	1,236
At southern edge of Itasca county,	1,230

Other elevations.

	Feet above sea level.
Summit of ridge in N. E. ¼ sec. 28, T. 54-26, about	1,617
Summit of ridge in secs. 11 and 12, T. 57-22, about (Probably the highest land in Itasca county).	1,675

* Road not constructed beyond this point when these elevations were determined.
† See altitude of lake Winnibigoshish given under Mississippi river on this page.
‡ The crossing of Armstrong creek is probably near the west line of Itasca county.
§ This point is near the eastern edge of Itasca county.
¶ This dam is constructed with capacity to raise the lake to 1,304 feet, but it is not expected that it will be raised higher than 1,300 feet.

	Feet above sea level.
Pokegama lake, formerly	1,271
Same, as raised by dam,	1,275
Bowstring lake,	1,321
Deer lake, south side of T. 57-26,	1,307
Wabano lake, centre of T. 57-25,	1,298
Trout lake, south side of T. 58-25,	1,300
Spider lake, west side of T. 58-25,	1,325
Ruby lake, N. W. ¼ T. 58-25,	1,312
Rainy lake,	1,111*
Rainy river, at outlet of Rainy lake,	1,111
Rainy river, below second rapids at outlet of Rainy lake,	1,108
Rainy river, at head of Koochiching falls,	1,107
Rainy river, at foot of Koochiching falls,†	1,084
Kabetogama lake,	1,121

Soil and timber. The soil of the county is similar to that of the counties to the south and west. In general the county may be divided into two districts as far as soil is concerned. The first of these includes the district described under the section devoted to topography as the drift district, and the second is there described as the lake-bed district. The first district includes the southern half of the county. Here the subsoil is till, or modified drift, and the surface soil is usually black loam. In but comparatively few districts does the till contain sufficient gravel and boulders to render the soil unfit for cultivation. Some areas of the stratified drift are too sandy, but as a rule the soil of the southern part of Itasca county is very fertile, and that of the northern part of the county is as fertile, if not more so. All the usual farm products of the state can be raised in this county, except perhaps the ordinary Indian corn. Farming has been carried on in the county but a comparatively few years, while that part of Ontario, bordering on the Rainy river, has been cultivated successfully for many years. Many of the swampy areas can be easily and cheaply drained, and thus many more areas of fertile ground can be added to that which is naturally well drained. The recent establishment of a state agricultural experiment station at Grand Rapids will undoubtedly materially aid in the settlement of the county by a farming community. Other remarks on the soil of Itasca county will be found in the appendix to this chapter.

None of the county is in the prairie area of Minnesota, and it was all originally timbered. The only exceptions to this statement are the marshy areas along some of the streams and lakes. Of course the most valuable timber is the white and red (Norway) pine, which have been extensively cut for lumber. Next in importance is the hard, or sugar maple. These three trees grow on the drier ground, and are, especially the white pine and sugar maple, almost exclusively confined to the areas of till. Another pine, the jack or Bank's pine, is quite common, but is of little value. It grows usually on sandy soil. Other trees are spruce,

*As determined by leveling from Ely along the international boundary, done by L. A. OGAARD for the Geological and Natural History Survey of Minnesota.

†By leveling by L. A. OGAARD for the Koochiching company this fall was found to be twenty-one feet in high water and twenty-four and a half feet in low water.

tamarack, balsam fir, elm, scrub oak, basswood, white birch and balsam poplar, the last two being abundant in areas in which the original forest has been destroyed by fire. Hardwood timber was the chief original growth in certain parts of the southern half of the county, as in T. 54–26, and it also occurs quite frequently in the northern half of the county, and also along the Rainy river. The white pine, the red pine and hard maple form the chief lumber supply of the county, which is by no means yet exhausted. The large swampy areas will soon become of importance as furnishing extensive supplies of spruce timber for pulp in paper making.

A very noticeable feature in the flora of Itasca county is the prevalence in certain areas of deciduous trees; in this respect the flora is in marked contrast with that of the counties to the east. In the northern edge of the county there is a very sudden change in the character of the timber as one passes, at the west end of Rainy lake, from the country of rock to the level plain of clays. On the former the timber (original growth) is usually not large and it is composed chiefly of conifers, while on the latter the growth is larger, and deciduous trees abound. Along the Little Fork and Big Fork (Bowstring) rivers there is plenty of good timber. The banks of the latter stream, along the last ten miles of its course, contain the following: basswood, soft maple, elm, black ash, white ash, white oak, aspen, white birch, balm of Gilead, box elder, three varieties of willow, ironwood, cottonwood, spruce, white cedar, Norway pine, jack pine, mountain maple, dogwood, cherry, alder and Juneberry. In the ten miles higher up the stream, groves of fine Norway pine are seen at intervals.

An interesting feature in many parts of Itasca county is the manner in which certain lakes are "growing up" to swampy areas. Thus, many of the swamps were formerly shallow lakes, although this is not the origin of all the swampy areas, especially those of large extent. In the shallow lakes vegetation is frequently quite rank and by its growth and decay adds slowly to the land surface, which thus gradually intrudes upon the water area. This process of filling in of a lake is more rapid in shallow water and along shores or in bays where the vegetation is not broken up by the action of waves. As the lake is becoming filled with vegetable matter the solid areas extend farther and farther from the shore, while the centre of the lake may still be open water. In many places this process of lake filling can be distinctly seen in operation. At the centre is an area of open water in which grow a few water plants (pond lilies, etc.) These increase in number farther from the centre and are gradually replaced by other plants (cat-tails, etc.,) which grow in marshy spots. Outside of this is an area which sustains moss, a few shrubs and grass. Such an area forms a meadow, and in the latter part of the summer this becomes drier and often furnishes a considerable crop of hay. Beyond this occur scattering, small tamaracks and spruces surrounded by the meadow plants. Such an area, *i. e.*, a comparatively open swamp with scattered, small tamaracks and spruces, is called a *muskeg*. (These muskegs are very common in Itasca county, and they sometimes are many miles in extent, but the larger ones probably do not originate from the growing up of shallow bodies of water.) Beyond the muskeg proper the trees increase in size and number, forming a typical tamarack or spruce swamp, and beyond this is higher and drier ground, usually supporting pines and hardwood, which represents the shore of the old lake. The relation of these different zones of plant growth in a lake which is being filled in can be seen in numerous localities and has been well described.*

*CONWAY MACMILLAN. *Bull. Torrey Botanical Club*, vol. xxiii, No. 12, pp. 500-507, plates 279-281, December, 1896.

GEOLOGICAL STRUCTURE.*

The rock formations which occur in Itasca county are of different ages, including both the oldest and the most recent known to man. The different strata are included under the following divisions, the most recent being placed at the top:

Post-glacial.
Glacial.
Cretaceous.
Animikie.
Post-Archean dikes.
Archean.

The Archean. The rocks included in this division are divided into three groups. These groups are the granitic rocks, the Coutchiching and the Keewatin.

(1). Granitic rocks. The term Laurentian has been applied frequently to these rocks, but as an age term it is objectionable because some, if not a large part, of the rocks which have been included under it are eruptives of later date than the Laurentian, while others may be of Laurentian (pre-Keewatin) age. Our present knowledge allows us to state positively that some of these granitic rocks are post-Keewatin (or later) eruptives, but it does not allow us to indicate just which rocks in Itasca county are actually of Laurentian age. It is not the writer's intention to affirm that there are no Laurentian rocks in Itasca county, but the fact still remains that no one is at present able to state with certainty where such rocks are, although it seems most probable that future work will enable us to recognize them. As far as known to the writer there is not in Itasca county, nor for that matter in the northeastern part of the state, any considerable area of rocks which might properly be called true gneisses. In fact all of the rocks heretofore mapped as Laurentian in this part of the state are more properly termed granites, or gneissoid granites when they possess parallel structures. It is true that a small part of the rocks mapped as Coutchiching (or Vermilion) might properly be called gneisses, but such rocks are of of small extent and are more conveniently and more accurately classed with the mica schists to which the name Coutchiching has been applied.

In composition these granitic rocks are mainly granites, *i. e.*, they are plutonic rocks composed of quartz, alkali feldspar and another mineral which may be hornblende, biotite, augite or muscovite. Sometimes more than one of the latter minerals are present, but the essential minerals are the quartz and alkali feldspar. As the quartz decreases in amount the rock varies to a syenyte, or to a dioryte when the feldspar becomes principally a lime-soda variety. Syenytes and diorytes are both found among the granitic rocks of Itasca county. These rocks are frequently more or less schistose and have some of their minerals elongated in a common direction, and can be termed gneissoid granites, but, as already stated, they do not form true gneisses.

*The discussion under this head is frequently rather summary and brief. Additional matter concerning the Archean in the vicinity of Rainy lake will be found in the appendix (Preliminary report on the Rainy lake gold region) to this chapter, while further information concerning the Giant's Range granite and the Animikie will be found in the chapters devoted to the special parts of the Mesabi iron range included in Itasca county, *i. e.*, the Pokegama Lake, Grand Rapids and Swan Lake plates.

Some of these rocks are intrusive into the surrounding rocks, while others may not be. But in no case in northeastern Minnesota do these Archean granitic rocks in themselves present good evidence of having once been sediments, no matter what theory may be proposed for their origin.* They can thus be considered as eruptive rocks, although of course not necessarily in every case of later date that the rocks with which we now find them in contact.

In Itasca county granitic rocks occur in several localities as given below. Additional localities for such rocks may be found when the county is explored more carefully.

Giant's Range. This belt of granite lies just to the north of the rocks of the Mesabi iron range. The granite forms a ridge which extends from the eastern side of the county southwest to and beyond the falls of Prairie river near the south side of T. 56-25 W. The southern limit of this granite belt can be quite definitely located, but the northern limit is unknown, being concealed by the drift. The southern limit enters the county near the northeast corner of sec. 12, T. 57-22, crosses the south line of T. 57-23 in sec. 33, crosses the west line of T. 56-24 near the northwest corner of sec. 19, and crosses the south line of T. 56-25 in sec. 33, beyond which outcrops are not known. This granite varies considerably, being sometimes of a reddish and sometimes of a gray color, at times of quite coarse grain and again finer. The chief minerals are quartz, feldspar, black mica (biotite) and hornblende. In places this granite takes on a parallel or streamed structure, as at the Upper falls of Prairie river, where the granite has been described as lying in nearly flat beds. In Itasca county this granite has not been found in contact with other rocks, except the Animikie strata which overlie it unconformably, so its age and nature cannot be determined. However, from the fact that it includes pieces of hornblende schist, and because it is geographically continuous with the Giant's Range granite in St. Louis county, which is thought to be eruptive into the Lower Keewatin, we can state with a good degree of certainty that the Giant's Range granite in Itasca county is an eruptive of an age later than the Lower Keewatin. And it is possible that it is of an earlier date than the Upper Keewatin, although this point is still to be determined. This granite will be spoken of again in the description of the Pokegama Lake sheet.

North of Net lake.† This granite varies from reddish to almost white in color, and is of fine or medium grain. Outcrops are reported from the east line of sec. 13, T. 66-22; east line, near north edge, of sec. 36, T. 66-22; and in secs. 22, 23 and 24, T. 66-23. At the two latter localities the granite is bounded on the north by mica schist. We have no definite information as to the relation of the granite to the adjoining mica schist.

Little Fork river. The rock here (T. 63-22) has not been studied as yet, but it is properly a syenyte or perhaps a dioryte, rather than a granite. It is a medium grained rock composed of pinkish feldspar, often in tabular forms, and a varying amount of biotite and hornblende, with perhaps some augite. Frequently the tabular feldspars are arranged with their flat sides approximately parallel. This rock is evidently of later date than the mica schist of this part of the region, for it contains numerous angular fragments of mica schist, as shown in the accompanying figure.

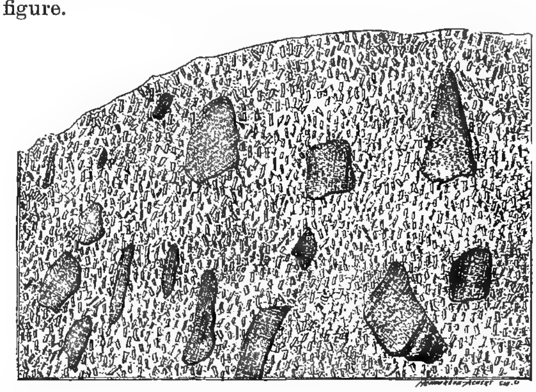

FIG. 16. FRAGMENTS OF MICA SCHIST INCLUDED IN SYENITE.
Rapid No. 13, Little Fork river.

Big Fork river. The first outcrop seen in descending the Big Fork (probably in the S. W. ¼ of sec. 35, T. 150-25) is of granite. The specimens collected here show a rather coarse-grained, hornblende granite, which is grayish, greenish or reddish in color. The feldspar varies from white to flesh colored and brownish red, the horn-

*Twenty-first Annual Report, pp. 50-54, 1893. See also further discussion of the granites in vol. v, of this report.

†For information concerning this area of granite, and also for specimens of it, we are indebted to Mr. C. L. CHASE, of Hastings, Minn.

blende is more or less altered to chlorite, and some epidote has been developed in the rock. One of the specimens contains a large proportion of quartz. Just below this, around a bend in the river, is an outcrop, on both sides of the river, of dioryte. This rock is somewhat decayed, and is dark gray or reddish, depending on the color of the feldspar. Another outcrop of nearly similar rock is seen near the east side of sec. 25, T. 61–27, and another at S. W. corner of sec. 30, T. 61–26.

Rainy lake. The granite rocks at Rainy lake are described in the appendix to this report. It may be stated here, however, that the granite rocks at Rainy lake in Itasca county occur in five areas. The first of these is at Koochiching falls; the second at the lake shore and islands in sec. 27, T. 71–23; the third on Grassy island in sec. 25, T. 71–23; the fourth in secs. 3 and 4, T. 70–22; and the fifth along the south shore of Kabetogama lake. As far as studied these areas of granite are thought to be eruptive into the surrounding rocks. This is especially true of the second area.

Other localities. From Mr. L. A. Ogaard, of Koochiching, we have received information of outcrops of granitic rocks at the following points: 1. Center of sec. 10, T. 68–24; outcrop about one-fourth acre in extent; biotite granite. 2. S. E. ¼ sec. 19, T. 64–24; outcrop about one-half acre in extent; granite. 3. S. E. ¼ sec. 11, T. 61–24; outcrop about one acre in extent; dioryte, but not clearly a part of the granitic rocks. It is possibly Keewatin.

*(2.) The Coutchiching.** This term has been applied to a large series of crystalline schists, mostly mica schists, of the Archean. They show no elastic structures, being completely crystalline, but from the regular banding similar to the bedding of sedimentary rocks, and from the fact that at times they seem to grade into the sedimentary rocks of the Keewatin, they have been considered, in the reports of this survey, as in the main a metamorphosed sedimentary series. The term was proposed for a mica schist series older than the Keewatin and as such it seems to have been correctly applied in the Rainy Lake district. But other crystalline schists have been mapped as Coutchiching (or Vermilion) which have been shown to be metamorphosed Keewatin sediments. These apparently owe their more crystalline character to the effect of intrusive granite and thus they are not necessarily lower in the geological scale than the Keewatin rocks, but may occur at any horizon in the Keewatin.†

The Coutchiching rocks are essentially mica schists, composed of biotite, feldspar and quartz, with some other accessory minerals and sometimes with muscovite or hornblende. The schistose structure is usually quite pronounced and in places alternations of beds of different color and composition can be seen. In general the strike of the schistose structure is east-northeast, and the dip varies. As far as studied no clastic grains have been recognized in these rocks, but from the fact that in places the Coutchiching rocks grade into the Keewatin clastics, as mentioned above, it seems clear that parts, at least, of what has been called Coutchiching represent considerably metamorphosed sedimentary rocks. These mica schists outcrop in many places along the Little Fork and Big Fork (Bowstring) rivers and along the south side of Rainy lake. They are more fully described in the appendix to this report.

The Coutchiching rocks may be referred to five areas; Net lake, north of Net lake, Little Fork river, Big Fork river, and Rainy lake. The relations of these areas to each other are not known, both on account of lack of exposures, the rocks being

* For the description and mapping of the areas of Coutchiching and Keewatin rocks along the Little Fork and Big Fork rivers we are dependent entirely on notes and specimens collected on hurried canoe trips along these rivers. We know very little of the relations of these two rock series along these rivers, and so the areas are outlined mainly by the lithological character of the specimens collected, the mica schist areas being referred to the Coutchiching, and the "greenstone" areas to the Keewatin.

† U. S. GRANT, *Twentieth Annual Report*, p. 59, 1893; *Twenty-second Annual Report*, p. 71, 1894. J. E. SPURR, *Twenty-second Annual Report*, p. 121, 1894. A. H. ELFTMAN, *Twenty-second Annual Report*, p. 159, 1894.

covered by glacial deposits, and also lack of exploration. The relation of these Coutchiching rocks to the surrounding rocks is not fully known. As stated above some of the so-called Coutchiching is a modified part of the Keewatin, while some of it, notably that at Rainy lake, within Minnesota, probably underlies the adjacent Keewatin unconformably. It is quite customary to find the Coutchiching mica schists cut through and through by granite dikes, and sometimes two series of dikes occur, one cutting both the schist and the other series of dikes. It also frequently happens that outcrops are found in which there are beds of granite or gneiss in the schist running parallel with its schistose structure. Such occurrences have often been described in the reports of the survey as "interbedded mica schist and granite." It is possible that some such occurrences really show alternations of bands of different composition of the same formation, but it is certain that in some cases the "interbedded" granite (or "gneiss") represents intrusive rock which has been forced between the layers of mica schist. This is especially clear when the bands of granite are seen at times not only running with the schist but also at times cutting across the strike and joining other bands or dikes.

Net lake. In only one place near the shores of this lake is there any considerable exposure of rock. This is on a small island, near the east side of the lake, just west of the Indian village. This island is composed of mica schist and gneiss cut by granite intrusions. The whole is then cut by a large greenstone dike from which stringers have been sent out across and through the other rocks. The dike strikes about north and south, and the mica schist strikes N. 58° E. and dips to the south of this direction at an angle of about 70°.

North of Net lake. We have reports of mica schist just to the north of the granite on the east line of sec. 13, T. 66-22; also to the north of the granite in secs. 22, 23 and 24, T. 66-23. The relation of the two rocks is not known.

Little Fork river. At the top of Oak rapids (N. E. ¼ sec. 22, T. 65-24) is an outcrop of mica schist in the bed of the river. This schist appears to be in place; it strikes E. 10° S. and dips S. 20°. Considerable mica schist is exposed on the northeast side of these rapids, and it is described as interbedded with a coarse muscovite granite or pegmatyte. Near the foot of the rapids the schist contains much quartz in veins, and many small garnets.

In sec. 31, T. 66-24, is a rapid (Dead Man's rapid) over mica schist "interbedded" with granite. The schist strikes north 80° E. and dips toward the south at an angle of 72°. It is very silicious and contains quartz veins, and sometimes weathers red. The beds of granite (or gneiss) are of all thicknesses up to three or four feet. Just below these rapids is an exposure of massive dioryte, and a short distance below this mica schist occurs again cut by granite.

Following down the river a number of other outcrops of mica schist are found. Frequently these are cut by, or "interbedded" with, granite or gneiss. The last* exposure is in the S. W. ¼ sec. 14, T. 68-25, where there is a low exposure of mica schist and granite in thin beds dipping north at a high angle and striking east and west. At this place figure 17 shows the relation between the mica schist and granite.

A ridge of mica schist and granite is reported by Mr. L. A. Ogaard on the county road from Koochiching to Grand Rapids. This ridge lies near the centre of the south edge of T. 67-24.

Big Fork river. The first exposure on this stream is about fifteen miles above its mouth. Here is an outcrop, about 200 feet long, of granitic rock on the west bank. Patches of mica schist occur in the granite and at the lower end of the exposure is mica schist banded with thin belts or sheets of granite. Phases of the rock occur in which garnets are abundant. About seven miles above this exposure is another one of mica schist. About thirty miles above the mouth of the river mica schist, veined and striped with granite, crosses the river. The strike is east and west.

A mile and a half below the mouth of Sturgeon river† a low moutonéed surface of gray mica schist protrudes from the water. Half a mile below the mouth of Sturgeon river a low outcrop of mica schist crosses the river from southeast to northwest. This outcrop would be invisible at any time except when the river was very low. The schist is cut by two veins or dikes of granite. One of these is narrow, fine grained and gray in

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*Prof. G. E. CULVER reports that an outcrop of hard, garnetiferous mica schist crosses the river four miles above its mouth. The strike is northeast and southwest, and the dip nearly vertical.

†This river comes from the west and enters the Big Fork river in the southeastern part of T. 155-25.

color, being composed very largely of quartz and feldspar and very little biotite and muscovite. The other is at least twelve feet wide; the specimens collected show a coarse mass of feldspar penetrated by quartz, forming an excellent example of coarse graphic granite.

At Big Falls (sec. 36 or 35, T. 155-25) the rock is granite and mica schist which is cut at the head of the falls by a diabase dike at least twenty feet wide, running north 10° east. A quarter of a mile below the falls mica schist and granite outcrop in the river. The strike is north 68° east, and the dip is south at a high angle. At the falls the rock is much disturbed and has no constant strike and dip. Less than a mile above the falls is an outcrop in the river of granite and mica schist. The strike appears to be east 50° south, and the dip southwest at a high angle.

No other outcrops occur until reaching a rapid about seventy-two miles from the mouth of the river; this is probably near the centre of T. 63-26. Here fine mica schist occurs projecting only a few inches above the water. This outcrop would be hidden by high water. One or two small veins of granite cut the schist. A short distance above this is more mica schist, striking north 68° east and dipping northwest, at a high angle. The schist is quite hard in places and contains hornblende, chlorite and garnets. A little above this and on the east side of the stream the strike changes to north 40° east. Here is a dike, about ten feet wide, which runs nearly north and south. The schist is hard, fine, siliceous and brittle next the dike. On the west side of the river is some gray granitic rock which appears like a fine-grained syenyte. Only a few feet of this is visible, but it seems to cut the mica schist.

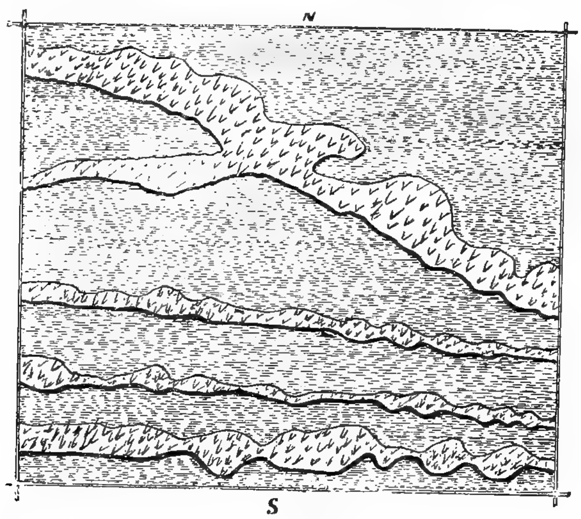

FIG. 17. MICA SCHIST AND "INTERBEDDED GNEISS" OR GRANITE.
Little Fork river, S. W. ¼ sec. 14, T. 68-25.

(3). *The Keewatin.* This series of rocks is of the age of the iron-bearing rocks of the Vermilion iron range. It is not developed extensively in Itasca county, at least as far as surface exposures are concerned, occurring in one locality on the Little Fork river, at several places on the Big Fork (Bowstring) river, west of Sturgeon lake, on Rainy river and at Rainy lake. The latter occurrence is described in the appendix to this chapter. At some of the other places the rock may be described by the ambiguous term "greenstone."

The relation of the Keewatin to the Coutchiching has already been spoken of in brief. No evidence on this point has been furnished by explorations in Itasca county outside of the Rainy Lake area, and here the evidence has not been worked out in full. Lawson was inclined to assume an unconformity between the Coutchiching and the Keewatin above. Recently the Minnesota survey has obtained conclusive evidence for the separation of the Keewatin rocks in St. Louis and Lake counties into two unconformable series, which are termed the Lower and Upper

Keewatin. Whether this separation can be extended into Itasca county is as yet unknown. There are, however, certain facts which favor the possible separation of the Keewatin in the Rainy Lake district into two series, but whether this separation can be made or not, is only to be determined by future work. Dr. A. P. Coleman, who has done considerable work in this district, is also of the opinion that such a separation can possibly be made.*

Little Fork river. At a rapid, probably in secs. 5 or 6, T. 63–22, is a low exposure of fine-grained green schist, striking east and west and standing vertical. This rock is quite hard and firm, and contains a few small quartz grains. It is cut by a dike of a fine-grained syenyte containing muscovite. About a mile below this is a rapid with an exposure on the south side of the river. The rock is a green mica schist strikingly similar to that mentioned above. The strike is N. 70° E., and the dip 90°. Half a mile below this is more green mica schist.

Big Fork river. At and near Rice rapids (probably in section 13, T. 61–26), and at three or more localities between Rice rapids and the mouth of Deer river, occur exposures of rocks which are referred to the Keewatin. The specimens collected at these points vary considerable in character, but in general may be called greenstones. They evidently represent at least three classes of rocks: (1) Clastic rocks, probably containing considerable basic volcanic material, (2) Surface igneous rocks, and (3) Intrusive diabase or dioryte. Under the first class are some very fine-grained green to greenish gray rocks, sometimes showing an indistinct slaty cleavage. At times these rocks are aphanitic and again they show small quartz grains imbedded in an aphanitic groundmass. The second class includes specimens quite similar to those of the first class; in fact, if it were not for the amygdaloidal cavities in the second class they could not readily be told microscopically from some of the first class. These amygdaloidal cavities are filled largely with quartz. The other class of rocks are rather coarse diorytes or diabases. There are specimens which do not clearly belong to either one of the three classes, but which show intermediate characters. In general all these rocks are considerably altered from their original condition.

At and near a dam on Deer river (sec. 23, T. 62–25) a hard green micaceous rock occurs; it is somewhat schistose, this structure striking N. 36°–40° E., and standing nearly vertical.

At Little falls, and in its vicinity, are other exposures of greenstone. Little falls is some ten or twelve miles below the mouth of Deer river and probably near the northeast corner of T. 62–26.

West of Sturgeon lake, in T. 60. The survey has received information, mostly from Mr. H. V. Winchell, of certain exposures in this locality. While the information is not definite enough to enable us to outline the extent of the Keewatin rocks in that part of the county, it seems quite clear that rocks of this age underlie much, if not all, of Ts. 60 and 61 in Rs. 22, 23 and 24. Lean iron ore occurs at southeast corner of sec. 36, T. 60–25, and at the west quarter post of sec. 7, T. 60–22. Keewatin rocks outcrop in sec, 12, T. 61–19. Near the south side of sec. 34, T. 61–22, hornblende schist occurs. At southwest corner of same section green schist, often massive and agglomeratic, outcrops; the strike is nearly north and south; farther west the strike is southeast and northwest. In secs. 7 and 18, T. 60–22, and secs. 11 and 12, T. 60–23, are outcrops of horneblendic and sericitic schist; strike northeast (and east?).

Rainy river. At the Longue Sault rapids (sec. 26, T. 160–27) hornblende schists outcrop along the river from about one-fourth of a mile above the rapids to near their foot, where they appear to be in contact to the south with a rather coarse-grained, reddish granitoid gneiss, which is exposed in two small islands at the foot of the rapids. The strike is with the direction of the river, or east and west, and the dip is toward the north at angles which are sometimes as low as 45°. Keewatin rocks occur on Canadian territory on the Pine river, whose mouth is opposite the northeast corner of T. 160–29; also on a small creek which empties into Rainy river about three miles and a half below the Longue Sault rapids. They also occur near the mouth of Rapid river, just west of Itasca county. (See report on Beltrami county, pp. 141).

Post Archean dikes. In the descriptions of the Coutchiching exposures some greenstone or diabase dikes have been mentioned. These dikes are essentially of of diabase, which in some places has been altered and decayed so that the rock has been called a greenstone. On the edges the dikes are very fine grained, showing that they were intruded when the surrounding rocks were not highly heated; the grain becomes gradually coarser towards the center of the dikes. The dikes cut the granitic rocks, the Coutchiching and the Keewatin, and are thus later than these, *i. e.*, they are post-Archean in age. Moreover, the dikes have not been subjected to

*Personal letter.

the intense pressure and foldings to which the Archean rocks have frequently been subjected, and they are therefore later than the last folding of the Archean. How much later, we are unable to say with certainty. None of these dikes have been found in the Animikie in Itasca county, but to the east of this county there are numerous diabase dikes in the Animikie rocks, but whether these are of the same age as the dikes in the Archean is not positively known. There are, however, some reasons (not conclusive, however) for assuming that these dikes in the Archean are of post-Animikie age and that they are of the same date as the great injections of basic igneous rocks which occurred after the Animikie, *i. e.*, in Cabotian and Manitou time. But as to whether these dikes date from the Cabotian or the Manitou, or from both, we cannot say.

In general the dikes have a northwest and southeast direction, although a few are found which vary from this direction.

On the Big Fork river about thirty-three miles above its mouth is an exposure of coarse, greenish gray rock which probably is part of a dike, although the surrounding rocks do not appear.

On the Rainy river about six miles above Manitou rapids is a dike, on the Minnesota side of the river. It forms a prominent bluff and cuts through green hornblende schists. At Manitou rapids the river flows over a large dike whose strike appears to be northwest and southeast. The contact with the enclosing rock is not seen, but there is a distinct gradation in grain, and the direction of the ridge or rock is taken as the direction of the dike itself. Another dike appears on the south side of the river one mile below the Longue Sault rapids, and another crosses the river about half a mile above the mouth of Rapid river. This last locality is near the west line of Itasca county.

Other dikes are mentioned in the appendix to this chapter.

The Animikie. After the Archean rocks had been deposited and elevated and more or less folded, the land again sank below sea level and the Animikie rocks were laid down. In Itasca county the only belt of these rocks we now have is along what is known as the Mesabi iron range, which lies just to the south of the Giant's range granite. The Animikie rocks enter the county on the east in T. 57–22, and extend in a southwesterly direction to the Mississippi river at Pokegama falls. To the west of this we know almost nothing of the Animikie rocks, nor have we any information which will lead us to state just how many miles west of the Mississippi river they go, but it seems most reasonable to conclude that these rocks, carrying with them the Mesabi iron-bearing rocks, extend for a considerable number of miles southwest from Pokegama falls.*

The strike of the Animikie in Itasca county is approximately east-northeast and west-southwest, varying from this general direction only locally. The dip is towards the south-southeast at a low angle which probably averages less than ten degrees. In the northeastern part of T. 56–24, there is an irregularity, mentioned in the description of the Grand Rapids plate, which seems to indicate that the Animikie possesses not only a monoclinal south-southeastward dip but that it also has been thrown into gentle folds by a force acting from the east or west. The quartzyte is

*See also pp. 65 and 68 of this volume.

sometimes, as at Prairie River falls, thrown into gentle folds whose axes run with the general strike of the Animikie.

In Itasca county in general the rocks of the Giant's range (granite) and the Mesabi iron range (Animikie) are pretty well covered by drift deposits so that outcrops are not common. For much of our mapping of these rocks we are dependent on test pits and diamond drill records. However, in the first ten or fifteen miles east of the Mississippi river there are more outcrops and fewer test pits than farther east in the county.

The kinds of rocks that occur in the Animikie in Minnesota allow that formation to be divided into four divisions;* these are, in descending order, as follows:

Upper or graywacke slate member, composed of black to gray slates and fine graywackes with some flinty slates and fine-grained slaty quartzytes.

Black slate member, composed largely of black, apparently carbonaceous, slates, frequently very fissile.

Taconyte or iron-bearing member, composed of taconyte and iron ore.

Lower or quartzyte member, composed of fine and coarse-grained quartzyte which is often conglomeratic in the lower beds. The Pokegama quartzyte, and also called at times Pewabic quartzyte.

These divisions have been made out from a study of the Animikie along the whole extent of the Mesabi range in Minnesota. In Itasca and St. Louis counties the lower two divisions are well developed, but lack of outcrops prevents us from knowing much concerning the upper two divisions, although the black slate member is known in St. Louis county; while in Cook county, near Gunflint and North lakes, the upper three members exist in their typical development, but the lower member is lacking.

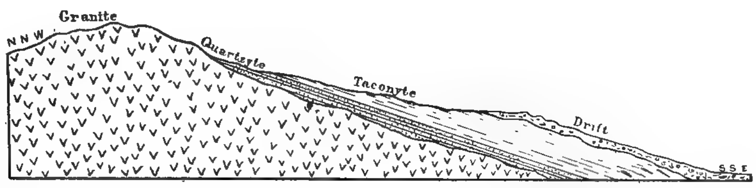

FIG. 18. GENERALIZED SECTION, SIX MILES LONG, FROM NORTH-NORTHWEST TO SOUTH-SOUTHEAST ACROSS THE MESABI IRON RANGE IN ITASCA COUNTY.

In Itasca county the quartzyte and taconyte members comprise the rocks of the Mesabi iron range. It is possible that the black slate member (and perhaps the upper member) exist in this county to the south of the outcrop of the iron-bearing rocks, but the covering of drift is so thick that these slates have not been found. However, it has been reported that fragments of black slate are abundant in the drift at a locality three or four miles south of sec. 22, T. 56 24. This would seem to indicate that the black slate member actually does exist in Itasca county.

The general relations of the Animikie rocks and the Giant's range granite in Itasca county are shown in figure 18, above.

(1). The Pokegama quartzyte consists in the main of a rather coarse-grained vitreous quartzyte, sometimes containing small pebbles and frequently iron stained.

***Twenty-second Annual Report*, p. 74.

In color it is white, gray, reddish and greenish. Typical exposures occur at Pokegama falls and at Prairie River falls. The quartzyte lies directly upon the granite of the Giant's range, and occupies a narrow belt between this rock and the taconyte member. The materials of the quartzyte were undoubtedly derived in large part from the granite. The width of the surface outcrop of the quartzyte belt is rarely more than half a mile, and the average width is less than this. At Prairie River falls the quartzyte dips 10° and 12° degrees towards the south-southeast. At Pokegama falls the dip is in different places about 15° towards south, 80° west; about 15° towards south, 8° east; 8° towards south, 22° east. The average of these is about 11°. If we assume that the quartzyte has an average horizontal outcrop of a third of a mile, and an average dip of 11°, the thickness will be about 335 feet. This is probably too large an estimate, and it seems probable that the average thickness of this quartzyte member in Itasca county is less than 300 feet.

(2). *The taconyte or iron-bearing member* is composed of rocks varying much in general appearance, but to which the name taconyte has been applied. One extreme variety of this rock is the pure iron ore (hematite, or sometimes magnetite), and the other extreme is regarded as a glauconitic greensand. All gradations between these two extremes are known. The most common types are finely banded rocks, which are red, gray and greenish in color. The banded varieties, when they contain iron ore, and especially when red, are known as taconyte and jasper, banded jasper and ore, jasper, or jaspilyte. These rocks have been described in full in Bulletin No. 10 and also in the Twentieth Annual Report. The iron ore deposits of the Mesabi range are confined to this iron-bearing member of the Animikie, and the ore occurs in bodies of various shapes at almost any horizon in this member. The maximum thickness of the iron-bearing member is not known in Itasca county, but estimates made to the east in St. Louis county place its thickness between 500 and 1,000 feet, with an average of about 800 feet. The belt occupied by this iron-bearing member of the Animikie is at least a mile in width and is in places known to be twice this distance. How much wider the belt may be is not known on account of the covering of drift and the lack of test pits.

The Cretaceous. After the Animikie, the next sedimentary rocks which occur in Itasca county belong to the Cretaceous. We have no knowledge of clastic rocks of intermediate age in this county. During the long time in which were deposited the Upper Cambrian, Silurian and Devonian strata in the southern part of the state, and the Carboniferous, Permian, Triassic, and Jurassic in other districts, Itasca county was either above the sea level, or, if during any of this time it was below sea level, all traces of sediments deposited at such a time have since been removed by erosion.

The Cretaceous strata are known in several places in Itasca county, but the unconsolidated nature of the deposits, when lacking in fossils, renders them sometimes somewhat difficult to distinguish, at least in a hurried examination, from glacial or post-glacial deposits. Thus, probably some exposures of these rocks have been overlooked. In general the Cretaceous strata are composed of clays, shales and sands, sometimes conglomeratic, with also some beds of lignite. These strata have a horizontal position. The facts, that large parts of the state probably now contain Cretaceous rocks and that the Cretaceous ocean extended over practically all of the state excepting Cook, Lake and the eastern part of St. Louis county, were first stated by the state geologist in 1878.* More recent work has tended to confirm this statement, and we are justified in saying that all of Itasca county was covered by the Cretaceous ocean, and that even now a large part of the county is underlain by strata of this age, although of course they are now largely obscured by the covering of drift.

Fossils collected from Cretaceous beds just to the east of Itasca county† show that the containing strata belong quite certainly to the Colorado formation‡ of the Upper Cretaceous, and it is safe to assume that all of the Cretaceous rocks in Itasca county belong to the Upper Cretaceous.

Little Fork river. The banks of a creek which enters this river probably in the S. E. ¼ sec. 9, T. 64–23, are formed of a fine, sticky, horizontally stratified clay, which becomes shaly on drying. This clay is fine, soft, bluish gray, and is in strata from one to three inches thick. The banks of the creek for one-fourth mile back from the river are twenty to thirty feet high and are formed of this clay, of which a total thickness of at least forty feet can be seen in this vicinity. A few cycloid fish scales and other fossils were found, and a microscopic examination of this shale by Messrs. Woodward and Thomas revealed characteristic Cretaceous Foraminifera. Less than a mile below this on the Little Fork river is a bluff of shale, forty feet high. A little below this, on the east side of the river, are clay hills eighty feet high. Six miles farther down the river, probably in sec. 1, T. 64–24, a stream, whose banks are of shale, comes in from the south. The hills in the vicinity are 75 to 100 feet in hight, and appear to be of horizontal Cretaceous strata. Another locality for these rocks is in sec. 36, T. 68–25.

Big Fork river. A few miles below the mouth of Sturgeon river (T. 155–25) the Cretaceous occurs in the river bank. In T. 64–27 are other exposures probably belonging to the Cretaceous. A few miles below the mouth of Deer river (T. 62–25), and also in several places along this river, between its mouth and Deer lake, the Cretaceous is again seen. In places these beds are hard and polished by the river's action.

Other exposures of Cretaceous rocks probably occur on the Little Fork and Big Fork (Bowstring) rivers, but they have not been carefully separated from the horizontal clays and sands which were deposited in the glacial lake Agassiz.

Other Cretaceous areas. It has been thought, and with apparently good reason, that some of the more noticeable hills in the southern part of Itasca county are composed of Cretaceous strata immediately underlying a thickness of only a few feet of drift. Such hills are the high ridge just southwest of Pokegama lake, and an oval hill in secs. 22 and 23, T. 55–26. Mr. H. V. Winchell reports that quite recently Cretaceous strata, very rich in fossils, have been encountered in the test pits of the Arcturus Iron company in secs. 13 and 24, T. 56–24.

Glacial deposits. As already stated, Itasca county is covered by deposits of glacial drift. The average and the maximum thicknesses of the drift are not definitely known. The thickness varies from nothing to an average of perhaps over fifty feet, while in the western and southern part of the county the drift is probably in places considerably over a hundred feet in thickness. In general it may be said that this covering of drift is thickest toward the west and southwest, and that it

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* *Bulletin Minnesota Academy Natural Science*, vol. i, pp. 347–349.

† H. V. Winchell. *American Geologist*, vol. xii, pp. 220–223, Oct., 1893.

‡ C. A. White. *Ibid.*, p. 221.

thins gradually toward the east and northeast. The only part of the county where the drift is very thin or almost wanting, is in the immediate vicinity of Rainy and Kabetogama lakes, but north of Net lake and along the Mesabi iron range, and just to the north of this the rocks are not so heavily drift-covered and they outcrop occasionally. In composition the drift of Itasca county is similar to that of the adjoining counties. Its material has been derived from the north, northwest and northeast, and perhaps from the east. Thus crystalline rock material is common, as are also fragments of limestone from the Winnipeg region and lignite from the Cretaceous. Boulders, while not scarce, are not so common as might be expected, although certain bouldery belts are known, especially along the upper part of the Big Fork river. In general it may be said that a large part of the drift material has not been transported far, having originated directly from the Cretaceous rocks of the county, and thus boulders will not be as common as in districts where the drift is chiefly derived from the Archean rocks.

*(1). Glacial striæ.** Below is a list of the directions of glacial striæ noted in Itasca county:

Rainy lake—	
N. E. ¼ N. W. ¼ sec. 30, T. 71-23,	south 40° W.
West line of sec. 29, T. 71-23, south shore of lake,	south 50° W.
S. W. ¼ S. W. ¼ sec. 29, T. 71-22,	south 55° W.
N. W. ¼ sec. 28, T. 71-22,	south 43° W.
Sec. 28, T. 71-23,	south 32° W.
East side of sec. 29, T. 71-22, south shore of lake,	south 60° W.
S. E. ¼, sec. 28, T. 71-22,	south 52° W.
S. W. ¼ S. W. ¼ sec. 24, T. 71-23,	south 60° W.
Near head of Black bay,	south 52° W.
Rainy river	
1½ miles below Koochiching,	south 40° W.
2¾ miles below Koochiching,	south 40° W.
3½ miles below Koochiching,	south 32° W.
Island in sec. 3, T. 159-25, 4 miles above Manitou rapids,	south 38° W.
Sec. 27, T. 169-27, 1 mile below Longue Sault rapids,	south 24° W.
Pine river,† first rapid,	south 24° W.
Pine river, second rapid,	south 24° W.
One mile above mouth of Rapid river, near west line of Itasca county,	south 38° W.
Little Fork river—	
Sec. 6, T, 69-25,	south 50° W.
T. 67-24,	south 40° W.
T. 67-24, near southwest corner,	south 42° W.
Sec. 31 (?), T. 66-24,	south 20° W. and south 80° E.
T. 64-22, near S. W. corner,	south 10° E.
Net lake, small island near east side of lake,	south 20° W. to south 24° W.
Big Fork (Bowstring) river—	
16 miles above mouth of river, T. 157-25,	south 44° W.
27 miles above mouth of river, S. part of T. 156-25,	south 58° to 62° E.
1½ miles below Sturgeon river, T. 155-25,	south 24° E.
Big Falls, near S. E. corner of T. 155-25,	south 80° E.
12 miles below Little falls, near centre of T. 63-26,	south 58° to 70. E.
Near same place,	south 10° W. and south 30° E.
A short distance above,	south 60° E.
Little Falls, near N. E. corner T. 62-26,	south 2° to 8° E.
One-eighth mile above Little falls,	south 2° E,

*Referred to the true meridian.

†This river empties into Rainy river nearly opposite the northeast corner of T. 160-29 W.

On Deer river, ½ mile above its mouth,	south 80° to 90° E.
Half way between mouths of Deer and Rice rivers,	south 70° to 80° E.
Sec. 5 (?), T. 61–25,	south 70° E.
A short distance above the last,	south 70° to 80° E.
Rice River rapids, upper exposure, probably in sec. 13, T. 61–26,	south 35° E.
Near the same place, below last,	south 65° E.
T. 61–26, perhaps in sec. 27,	south 70° E.
T. 150–25, probably in S. W. ¼ sec. 35,	south 5° to 0° E.
Pokegama falls,	south 50° E.
Prairie river, lower falls, S. E. ¼ sec. 34, T. 56–25,	south 4° to 10° E.

From an examination of the directions of these striæ at Rainy lake, on the Rainy river and on the lower parts of the Little Fork and Big Fork (Bowstring) rivers, it will be seen that the last ice movement thus recorded in the northern part of Itasca county had a general southwesterly direction. A lack of a sufficient number of known striæ in the southern part of the county prevents us from stating definitely the direction here, but it was most probably more nearly south than southwest. Some of the directions recorded on the upper parts of the Little Fork and Big Fork rivers are rather anomalous. They indicate a motion either from the northwest and west toward the southeast and east, or from the southwest and east toward the northwest and west. The latter direction is regarded as the true one by Mr. Warren Upham, who refers this direction of motion to the fact that the ice-sheet in the western and northwestern part of the county disappeared, probably on account of melting by the waters of the glacial lake Agassiz, before the ice in the central part of the county. The ice thus left would move out toward the areas free from ice and some of it would thus move west, or north of west, producing the anomalous striæ.*

The glacial deposits take four chief forms: (1) Till, non-morainic; (2) Morainic accumulations; (3) Modified drift, and (4) Deposits in the glacial lake Agassiz. Each of these types of deposits has characteristic features, but the exploration of the county has been so incomplete that we are unable to outline or describe all the different areas.

(2). Moraines. Considerable areas are covered by rough, hilly drift representing the deposits from the end of the ice where it remained in approximately a constant position for some time. Four such morainic belts are supposed to cross Itasca county. The most southern has been termed the ninth or Leaf Hills moraine. This is represented by the hilly district in the southern part of T. 53–24, and the southwest corner of T. 53–23. This moraine is crossed by the Mississippi in sec. 26, T. 53–24. The tenth or Itasca moraine enters Itasca county in T. 53–27, passes northeastward along the south side of Siseebakwet lake in T. 54–26, includes most of Pokegama lake and also Trout lake in T. 55–24, and presumably continues through T. 56–23, leaving the county about the north part of the east side of T. 57–22. One

*It is also quite reasonable to assume that these anomalous striæ were produced by ice of the Lake Superior lobe moving towards the west, and even north of west.

peculiar kettle occurs on this moraine. It is in the top of the highest hill in sec. 21, T. 56–24. The hill is about 150 feet above the little stream near its base and is separated from adjoining hills. The kettle, which simulates a crater very closely, occupies nearly the whole top of the hill and is about sixty feet deep and fifteen rods across the top of its narrow rim.

The eleventh or Mesabi moraine is thought to be represented by low hills just north of lake Winnibigoshish. It is strongly developed in the northern part of T. 56–27, passes along the south side of Deer lake in the northern part of T. 56–26, then turns northward and includes the hilly lake country in the east parts of T. 57–26 and T. 58–26, and the west parts of T. 57–25 and T. 58–25. This district probably represents a reëntrant angle in the ice front. The moraine passes eastward through the north part of T. 57–25, and presumably continues directly eastward approximately coinciding in position with the Mesabi moraine at the eastern limit of Itasca county.

The twelfth or Vermilion moraine, as mapped by Mr. Warren Upham, is represented by hills just to the south of Net lake. Its western extension is not known, but it may pass into the area of the glacial lake Agassiz and be obscured by the deposits of that lake.

Prof. N. H. Winchell, in studying the drift characters in St. Louis county, has reached the conclusion that the Vermilion moraine does not pass south of Net lake, but that it runs more to the north, and enters Itasca county near the west end of Kabetogama lake, being continuous with the line which separates the rocky surface at Rainy lake from the level plain of clays to the west and southwest of this lake.*

In the mapping of Beltrami county, Prof. J. E. Todd finds five morainic areas, south of the highest shore line of lake Agassiz, which pass into Itasca county. On the Itasca county map these moraines are represented as entering the county, but we have no information which will allow us to designate with certainty their position for any considerable distance east of the Beltrami-Itasca county line.

(3). Modified drift occurs in several areas in the southern part of the county. The most extensive area is the flat country between the Mississippi and Swan rivers, extending from Blackberry southeast to the limits of the county. Other areas occur in the triangular district bounded on the east, south and west by the Mississippi river in T. 55–27, also north of the river in the vicinity of Ball Club lake.

(4). The glacial lake Agassiz.† This body of water covered a considerable part of the northern half of Itasca county during the closing stages of the Glacial period. Unfortunately the shore lines and the deposits of this glacial lake have not been studied in detail in this county. The highest shore line, whose approximate location is shown on the county map (plate 65) enters the county on the west in the northern

* See chapter on and map of the north part of St. Louis county in this volume.

† For a full description of this lake, see "The glacial lake Agassiz," by WARREN UPHAM. Mon. xxv, *U. S. Geol. Survey.*

part of T. 153–29, at an altitude of over 1,200 feet above sea level. It extends eastward and southeastward, and we have its probable location where it crosses the Big Fork river.* This is near the western edge of T. 62–25, and here the beach is thought to be about 1,250 feet in altitude. It then is thought to run northward, turning east probably in the southern part of T. 65–25, and crossing the Little Fork river near where that river is crossed by the county road from Grand Rapids to Koochiching. This is in the southeastern part of T. 65–24. From this point the line runs northward and then eastward, leaving the county in T. 69–22, at an altitude of something over 1,250 feet. It is only just to say that we have no certain record of this beach, as a beach, in Itasca county, but the above location is given from a knowledge of elevations and the general character of the country within and without the old lake area.

The character of the surface to the north and west of the shore of lake Agassiz is noticeably different from that to the south and east of this line. As has already been stated, the land included in the area of this lake is in general a plain with a flat, monotonous surface. The land has such a small slope that large parts are covered by swamps. The origin of the present surface can best be explained by assuming that as the ice retreated the land was a gently rolling or flat area covered with glacial deposits. These deposits were then covered wholly or in part by material deposited in the glacial lake. These lacustrine beds exist in considerable force along the Rainy river and the lower parts of the Big Fork (Bowstring) and Little Fork rivers. It is probable that they thin out or nearly disappear at the southwestern part of this lake in Itasca county. It is most plausible to refer these beds, which are mostly of sands and clays, to material derived directly from the ice and deposited in the lake.

The place where the marked contrast between this plain of lacustrine deposits and the surrounding areas can be best seen is at the west end of Rainy lake. The lacustrine deposits, which are in full force along the Rainy river, here end abruptly and are replaced on the east by a surface of rock and scanty drift among which lacustrine beds seem to be entirely lacking. As yet no evidences of beaches have been found here, and, moreover, some of the lacustrine beds are a few feet above the level of Rainy lake. It is thus seen that the body of water in which these deposits were laid down must have covered Rainy lake, unless it was prevented from doing so by the ice-sheet. Moreover, from our knowledge of the altitudes of the shore lines of lake Agassiz farther west, and the elevation of the land which has taken place toward the northeast since the time of lake Agassiz, it is safe to assume that, if this lake did extend over the area now occupied by Rainy lake, the surface of the water of the

* *Seventeenth Annual Report*, p. 434.

glacial lake was here in the vicinity of one hundred feet above the present surface of Rainy lake. There was certainly an ice boundary to this glacial lake along part of its northern area, preventing the water from flowing out into Hudson bay. It seems to explain the facts better to assume that at one time, not necessarily at the end of the life of the glacial lake, the ice border of the lake retreated comparatively slowly in the district along the Rainy river. During this period much material derived directly from the ice was deposited as sediment in the water of this lake. These lacustrine deposits covered up the true till, which was derived directly from the ice-sheet, and which was not distributed by, and laid down as sediment in, the waters of lake Agassiz.

The line where the lacustrine deposits end can be drawn from the west end of Kabetogama lake northwest past the west end of Black bay and the outlet of Rainy lake. This line is approximately at right angles to the last ice-motion in this area. To the west and south of this line these deposits occur, while to the east and north of it they seem to be entirely lacking. It may be that the ice retreated very suddenly from this line, or it is possible that this line represented the ice-boundary of the lake, when it was drained away to Hudson bay. Either supposition will account for the sudden ending of the lacustrine deposits. The idea that this line represents the ice-boundary of lake Agassiz has been proposed by Lawson, but Upham regards it as rather improbable. To the writer it seems that the idea that this line represents the line of the ice-boundary of lake Agassiz at one time, but perhaps not necessarily at the end of the life of the glacial lake, is quite in accordance with the observed facts. As has been stated above, professor Winchell regards the Vermilion moraine as practically coincident, in the vicinity of Rainy lake, with the line separating the country covered by lacustrine deposits from that in which they are lacking. This moraine represents a considerable period during which the front of the ice-sheet was practically stationary, and it would seem that during this same period the ice-front was stationary near the limit of the lacustrine deposits, and that here was, for a time at least, the ice-border of the glacial lake Agassiz. After this moraine and the lacustrine deposits were formed, the ice must have retreated very rapidly, leaving a comparatively small amount of drift material, and practically no lacustrine deposits on the country north and east of this limit.

The thickness of these lacustrine deposits in the glacial lake Agassiz necessarily varies considerably, and the limits of the beds are not fully known, except on the northeast, as already mentioned. These deposits are well developed on the lower parts of the Big Fork (Bowstring) and Little Fork rivers, and along Rainy river. The following description is taken from Lawson's account of these beds.*

* *Geol. Survey of Canada*, Annual Report, vol. iii, part 1, pp. 170F-173F.

"These brief notes by earlier observers of the formations through which Rainy river cuts its way, do not give a sufficiently clear or comprehensive account of their character, their distribution or their geological history. I shall, therefore, attempt to supplement them by observations I have been enabled to make in the field myself, as well as to point out the connection of the facts adduced with those that have been observed by others in the study of post-glacial phenomena in adjoining regions. I am at a loss to understand Dr. Bigsby's statement that he saw no marks of stratification in the banks of the river. There are abundant and distinct evidences of the deposition of the greater part of the formations in stratiform layers or beds. They are first observed on Rainy lake on the west shore of Sand bay, as bedded clays. Between Rainy lake and Fort Frances, the banks of the river are composed of light colored, more or less sandy and calcareous clays with numerous pebbles of yellow or cream-colored limestone. The banks rise about ten or twelve feet above the surface of the river at its mean hight, and the country back from the river is flat. Below the falls of Fort Frances the river sinks in level, between twenty-two feet and twenty-five feet. And as the surface of the country remains flat, the hight of the river banks below the falls is increased by this amount. The banks here present a more or less steeply scarped aspect, a character which they retain almost continuously to the mouth of the river, although there are occasionally short stretches of sloping banks or low shores which are wet or dry, according to the hight of the water in the river. For a long distance down the river from the falls, evidences of stratification are not very prominent in the banks. The clay is very calcareous or marly, and crumbles readily when dry, forming a steep talus. The bedding can, however, be seen occasionally in the short scarp which rises above this talus quite distinctly. In these cases, thicker beds of a calcareous or sandy clay, with numerous small pebbles, are generally separated by thin partings of purer unctuous clay. The thicker beds usually vary from two inches to six inches in thickness, and are often much more sandy than clayey. For the first three miles below the falls, the underlying glaciated rocks upon which the formation rests crop out occasionally on both sides of the river. From these exposures I should judge that the mean level of the rocky surface of the country along this part of the river would be but little below the surface of the river, and that we have in the hight of the banks a vertical section nearly equal to the mean thickness of the formation, which would, therefore, be between thirty feet and forty feet. After turning the bend three miles below Fort Frances, no rocks crop out along the river for over twelve miles. Throughout this distance, the character of the banks varies but little and presents only a few points of special interest. On the Indian reserve opposite the mouth of Little American or Little Fork river there is a peculiar terrace-like ridge running parallel with the river a few hundred feet from the water's edge. It is observable only for a short distance where the Indians have cleared away the bush. Between the Little and Big American rivers on the Canadian side there can be seen an extensive, apparently unstratified mass of clean, unctuous, blue clay underlying the bedded marly clays and sands of the upper portion of the bank. Below the Big American river the bedded clays, sandy and marly clays and sands prevail, and the lower unstratified blue clay was not again observed for a considerable distance. On Mr. George Singleton's farm (sec. 9, T. 5, S. R. xxviii), the glaciated surfaces of the old rocks outcrop from beneath these post-glacial deposits, not only on the river banks, but over a considerable area in the rear of his farm, the rock being a hornblende-syenyte gneiss. Rock exposures are more common from this point on to the bottom of the Longue Sault than anywhere else along the river, and some of the more prominent points appear to have been islands in the fresh water lake, in which the post-glacial formations were deposited. The latter cannot be on the average much more than twenty-five feet or thirty feet thick along this part of the river. The surface of the country rises gently, however, on the north side of the river, and at the back of Mr. Lutterel's farm (sec. 22, T. 5, S. R. xxviii) a low, flat gravel ridge was observed which probably lies on top of the beds exposed at the river bank. Between this point and Manitou rapid many more boulders of Archean rocks were observed imbedded in the strata of the river banks than had been noticed higher up the stream, although they are not prominent near the rapid itself, the formation, as observed by Dr. Bigsby, being unusually clayey there. Near the eastern limit of the Indian reserve at Manitou rapid there many be seen on the north side of the river a mass of unbedded clay with pebbles to a thickness of ten feet to fifteen feet above the surface of the river, and resting upon this four feet of evenly bedded sandy clay in which the pebbles are mostly yellow colored limestone. Down near the rapid these upper beds are wanting just at the water's edge and the lower clay only is seen. This lower clay is probably the same formation as that noted between the Big and Little American rivers.

"Below the Longue Sault Rapids for some miles the banks of the river on either side, wherever the scarped faces permit of close observation, show only bedded marly clays, and clayey sands with pebbles. If the unstratified lower clay underlies these beds, as appears quite probable, it is concealed by the soft talus that has fallen from the scarp. Mr. Cameron informed me that he had sunk a well four miles back from the river on a logging road (sec. 21, T. 4, S. R. xxv) for twenty-two feet, and had bored a further forty feet through formations similar to those on the bank of the river before he struck solid rock. He obtained water at this depth of sixty-two feet, but found it extremely hard, a fact due to the abundance of calcareous matter in the loose strata through which water must percolate before reaching the comparatively impermeable surface of the underlying hard rocks. The formations up the Pine river, as far as the second rapid, are, as on Rainy river, bedded marly clays and clayey sands, together with gravel made up very largely of limestone debris. At the first rapid on Pine river a gravel ridge which lies on the glaciated surface of the rock has been cut into by workmen engaged in the construction of a dam across the rapid. The gravel is rather fine, mostly calcareous, and much mixed with clayey matter. In it were found large numbers of fresh-water shells, together with some fragments of bones of the buffalo (*Bos americanus* Gmelin). Fresh-water shells were also found in the beds on Rainy river, at the confluence of Pine river, and at various points below this, particularly, however, in the bedded sands and clays at

the mouth of Beaudette river. Although the shells at these points are numerous, the species are few. The following have been identified by Mr. Whiteaves: *Sphærium sulcatum* Lamark; *Sphærium striatinum* (?) Lamark; *Planorbis* (*Helisoma*) *bicarinatus* Say; *Limnæa* (*Limnophysa*) *desidiosa* Say (one, broken). Near the confluence of Beaudette river, and from that point on to the mouth of Rainy river, the banks still retain their abruptly scarped aspect rising from ten feet to twenty feet above the river, but the formations composing them gradually change in character, and the clay gives place to a fine light-yellow muddy sand, bedded often with very thin partings of clay. A third of the way from Beaudette river to the mouth of Rainy river, this yellow sand is observed to rest upon a pebble conglomerate made up of limestones and Archean pebbles imbedded in a partially hardened mud matrix."

Post-glacial deposits. These deposits are of limited extent and take the form of alluvial material along the larger rivers. Such deposits are still being laid down in high water along the river flood plains. Alluvium occurs along the Mississippi river, especially in T. 53-24, and T. 54–24, also along the lower parts of the Little Fork and Big Fork rivers. The Rainy river, contrary to expectation, does not seem to be depositing alluvium; it is a river with practically no flood plain. These statements are made from a knowledge of the upper part of this river valley and the published accounts seem to show that the rest of the valley is similar to its upper part. The Rainy river from the outlet of Rainy lake to Koochiching falls, a distance of about three miles, flows in a shallow, steep-sided trench, the water, even in low stages, reaching nearly from one steep bank to the other. The river in high water does not reach to the top of these banks and so no alluvium is deposited. Below the falls, for a distance of several miles, the conditions are the same, except that the banks are twenty to forty feet higher, and here also no alluvium occurs.

MATERIAL RESOURCES.*

Water-powers. There are numerous rapids and small falls along the streams of this county which, by a little improvement, could be developed into good water-powers. Pokegama falls and Grand rapids on the Mississippi, Big falls on the Big Fork (Bowstring) river and several smaller falls on this river and on the Little Fork are examples of these water-powers. By far the largest water-power in the district is that of the Koochiching falls (see plate O, figure 2). Here the Rainy river descends from twenty-one to twenty-four and a half feet, the amount of fall varying with the stage of the water. It has been estimated that there are 12,000 cubic feet of water flowing over this fall every second, and the power here generated averages 30,000 horse-power, with a probable minimum of 20,000 horse-power. This is thus seen to be by far the largest water-power in the state, much exceeding that at St. Anthony falls. A dam of from five to ten feet at the head of these falls would increase the hight of the falls as many feet, and would also raise the level of Rainy lake from two to seven feet, thus furnishing an immense mill-pond with an enormous supply of water for use in times of low water in the river. The value of this water-power as an aid in the development of this part of the state cannot be overestimated.

*See also under "Other resources," in the appendix to this chapter.

Clays. As yet no clay beds have been worked in Itasca county, but there is no reason why some of the glacial and post-glacial clays will not be used for brick making as the county becomes better settled. The best clays are probably in the Cretaceous strata. These have not been explored carefully, but it seems probable that much good pottery clay, and even clay for finer material, can be obtained from these beds. Kaolin occurs in connection with the Cretaceous strata in the Minnesota River valley, and may also be found in Itasca county.

Mica. Some of the coarse pegmatyte dikes in the Rainy Lake region contain plates of mica of considerable size, and a mica mine has been reported as started near Kettle falls in St. Louis county.

Gold. The appendix to this chapter deals with the gold discoveries in the vicinity of Rainy lake, and it will not be necessary here to repeat information which can be found there.

Iron. The Mesabi range traverses the county from the east side of T. 57–22, southwest to the Mississippi river at Pokegama falls. Already deposits of hematite ore have been found along this range in Itasca county, as at the Mesabi Chief mine and on the land of the Arcturus Iron company. The iron of the Mesabi range is discussed elsewhere. It is sufficient to say here that the taconyte or iron-bearing member of the Animikie, which is the horizon of the extensive and numerous deposits of hematite in St. Louis county, exists in Itasca county, as described and as shown on the geological map. The exploration of this belt of taconyte has not been as thorough as might be desired, and the results of the exploration are not as encouraging as in certain localities in St. Louis county. Still the future will probably show the existence of other hematite deposits in Itasca county, although it is not thought that as many and as rich deposits will be found as exist in St. Louis county.

Rocks of the same age as the Vermilion iron range rocks exist in the vicinity of Rainy lake, but we know of no prospects for iron ore discoveries in this district in Itasca county, although farther east in Ontario iron ore occurs in rocks of the same age.

The Vermilion iron range extends into Itasca county from the east, but its limits are not definitely known. Its rocks are deeply covered by the drift west of the central part of the county, but in Ts. 60 and 61, Rs. 22, 23 and 24, outcrops of the characteristic rocks of the Vermilion iron range are reported. Although parties of the survey have not visited this district, we feel certain that rocks of the same age and nature as the rocks of the Vermilion iron range exist here, and that this district is a promising one for explorations for iron ore. Jaspilyte and lean ore already have been reported from this locality.

GEOLOGICAL MAP.

On the map here presented (plate 65) the areas shown to belong to the Archean, Animikie or Cretaceous are those in which the rocks actually outcrop pretty continuously or in which we are reasonably sure that they exist immediately under the drift. It is thought best to thus represent knowledge which is definite, rather than

to represent the *supposed* extent of the different formations. On the map the areas described in this chapter as containing Coutchiching rocks are indicated by the title "hornblende and mica-schists." The county has been too little explored to enable us to map with accuracy the different types of drift deposits. We have shown the actual and most probable extent of the moraines in the southern part of the county, but have not attempted to separate the areas covered by till from those covered by modified drift. The extent of the alluvium covered areas is not accurately known. Much of the southern part of the county has been unstudied and it is simply represented as covered by the drift. The area included in lake Agassiz is known to have at the north a considerable covering of lacustrine deposits, while on the south and especially the southwest these deposits in all probability do not cover the till to any great extent, if at all. Our present knowledge will not enable us to outline more definitely these two types of surface in the bed of the old lake.

ROCK SAMPLES.

The following rock samples, illustrating the geology of Itasca county, have been collected by the survey:
N. H. Winchell's series, 1,521 to 1,539.
H. V. Winchell's series, 83 to 159, 213 to 285, 326 to 327.
U. S. Grant's series, 1,025 to 1,055.
Museum Register, 8,000 to 8,016, 8,018, 8,021, 8,024, 8,025, 8,112 to 8,114.

APPENDIX TO THE REPORT ON ITASCA COUNTY.

The northeastern corner of Itasca county contains the only gold mine in the state, and, as the Rainy Lake gold district is well known, it was thought best to introduce here information concerning this district. In the latter part of 1894 a preliminary report was written on this district; as parties of the survey have not since visited it, nothing of importance can now (January, 1897) be added to that report. It is consequently largely reproduced here with very few alterations except the omission of certain parts not directly dealing with the region in question. The report was published early in 1895 and occupies pp. 36 to 105 of the twenty-third annual report of this survey. It is a matter of some congratulation to the authors of this report that their statements in the conclusion do not need to be altered, unless it is to make them more emphatic. The Little American mine is the only producing gold property on the Minnesota side of Rainy lake, but in several places in Canadian territory adjoining the lake, developments are such as to show definitely that profitable gold mining can be carried on in the Rainy Lake district.

PRELIMINARY REPORT ON THE RAINY LAKE* GOLD REGION.

By H. V. WINCHELL and U. S. GRANT.

INTRODUCTORY.

This report makes no pretension to be an exhaustive description of the Rainy Lake country and of the gold interest centered there. The time allowed for study in the field and in the laboratory has been entirely insufficient for the preparation of anything but a preliminary paper. The authors have, however, endeavored to present a report which will give some precise and reliable information concerning this region, the occurrence, richness and

* There is an idea, more or less prevalent, and it has been stated in print, that the name of this lake is derived from a corruption of the French names Regnault or René, neither of which has the same meaning as the English *rainy*. There are no good grounds for this idea, which appears to be merely an assumption. The earliest map we have seen, on which this lake is represented, is that by Ochagach, an Assiniboine chief, who traced it for Verendrye in 1730. On this map Rainy lake is called "*Lac Tecamamisuen*. The next map on which Rainy lake is shown is that of Buache, entitled "Carte physique des terrains les plus élevés de le partie occidentale du Canada" and published in 1754. On this map Rainy lake is designated as "*Lac Tecamamiouen ou de la Pluie*," which is sufficient proof that at that early date, 140 years ago, the lake was known to the French explorers as *Lac de la Pluie* (Lake of the Rain). There are thus most excellent grounds for the belief that the name Rainy lake is a direct translation of the original French designation. Most likely, also, the French name was a translation of the Chippewa name.


GEOLOGICAL
MAP OF THE
RAINY LAKE GOLD REGION
in Minnesota and Ontario.
By H. V. Winchell and U. S. Grant.
1894.
EXPLANATION.
Post-Archean .... Diabase.
Archean
Keewatin
Green and sericitic schists, graywackes, and altered eruptives.
Conglomerates
Gabbro.
Coutchiching
Mica schist.
Granites, syenites, and gneisses.
The shore lines and rock formations in Canadian territory, except in a few localities, are derived from the Rainy Lake sheet of the Geological Survey of Canada, prepared by Dr. A. C. Lawson.
Contour Lines are drawn approximately in Minnesota for each 50 feet above the sea
0 1 2 3 4 5
Scale of Miles.
RAINY LAKE
KABETOGAMA LAKE
NAMEKAN LAKE
SHOAL LAKE
BAD VERMILION LAKE
RAINY RIVER
SEINE RIVER
BLACK BAY
SAGINAW BAY
BLEAK BAY
SEINE BAY
SWELL BAY
STANJIKOMING BAY
SAND BAY
JACKFISH BAY
HOPKINS BAY
RICE BAY
RED GUT BAY
GRASSY LAKE
FORT FRANCES
KOOCHICHING
RAINY LAKE CITY
SEINE RIVER CITY
DRYWEED ISLAND
Sand Point Island
International Boundary
Brule Narrows
Manitou Rock
Pine Islands
Cranberry Bay
Cormorant Bay
Rat River
Hale Bay
Big Pine Id.
East line of Itasca County
West line of St. Louis County
71-23
70-22
70-21
70-20
70-19
70-18
69-21
69-20
69-19
69-18
93°

necessary treatment of the ores, the geological structure, and the other resources. It is hoped that this report will be of value as an easily accessible source of information to intelligent persons who desire to gain some knowledge of this district, as well as to those who are now in the region or who are contemplating visiting it.

The description of the geology and the general physical features of the Rany Lake region applies especially to that part of the lake and its shores lying in Minnesota, but most of these statements will hold equally well for the territory on the other side of the International boundary. When certain features find better development in Canadian territory this fact will be mentioned. The geological observations of the authors have been supplementary to, and in a large degree confirmatory of, the reports on this region written by A. C. Lawson* and H. V. Winchell.† To these reports we are indebted for corroboration of many of the facts observed in the field, and in some cases for statements which are essential to this report, but which we are unable to make wholly on our own authority. This general acknowledgment will suffice to make it unnecessary to give references in cases where our observations agree with those of the above mentioned authors, but where we are entirely indebted for certain statements to the previously published reports reference will be made to the source of the information.‡

GENERAL FEATURES AND GEOLOGY.

I. GENERAL FEATURES.

Location. The area shown on the accompanying geological map (plate N) comprises the region here reported on. Roughly speaking, it includes the northeastern corner of Itasca county, the northwestern corner of St. Louis county and a belt of country, eight to fifteen miles wide, immediately to the northward in Ontario. More accurately the region mapped and described extends from the east side of range 18, St. Louis county (about longitude 92° 34′ west of Greenwich), west to the west line of range 24, Itasca county (about longitude 93° 29′), a distance of forty-two miles; and from the south side of township 69 (about latitude 48° 25′) north to latitude 48° 45′, a distance of twenty-three miles. The map thus includes 966 square miles, which are about equally divided between Minnesota and Ontario.

Rainy lake comprises the larger part of the water surface in the area mapped. It extends along the international boundary from Kettle falls, in sec. 30, T. 70–18, westward to its outlet in sec. 25, T. 71–24, a distance of about forty-one miles. Less than one-fourth of the surface of the lake lies in Minnesota, and several bays extend north and northwest of the area shown on the geological map.

Rainy Lake City, which was the first town started in this district in Minnesota, is situated in sec. 43, T. 71–22, Itasca county, and is 135 miles in a straight line north-northwest of Duluth and 250 miles north of St. Paul and Minneapolis. Koochiching, Itasca county, and Fort Frances, Ontario, are on opposite sides of the Rainy river at Koochiching falls, twelve miles west of Rainy Lake City and two and a half miles west of the outlet of Rainy lake.

Topography. Rainy lake is a very irregularly outlined body of water with many crooked bays and numerous islands, which vary in size from mere reefs to those several square miles in extent. The surface of the lake, inclusive of islands, has been computed to include 344 square miles. Its extreme length is from the east end of Hale bay, which is about four miles east of Kettle falls, northwestwardly to the extremity of Northwest bay, in all, fifty-five miles. The extent of the lake east and west is forty-six miles, and the extreme width (north and south) thirty-three miles, of which twenty-three miles are in Canadian territory. On account of the irregular shape of the lake and its numerous points and islands there is no very considerable stretch of open water, but in a few places the view is unobstructed for ten to fifteen miles in one direction. That part of the lake lying along the international boundary consists of an eastern arm extending from Kettle falls to Brulé narrows, and the southern side of the main part of the lake lying west of Brulé narrows. The eastern arm is twenty miles long (east and west) and from two to five miles wide. The main part of the lake has several large bays running north into Ontario; in fact, most all of this section of the lake lies north of the boundary line. The only extensive bay on the Minnesota side is a shallow body of water lying in the north half of T. 70–22, known as Black bay, or as Rat Root lake by the Indians.

The land surrounding Rainy lake, except on the west, slopes toward the lake, which thus receives the drainage of a considerable area. The extent of the drainage basin of Rainy lake is some 16,440 square miles, of which 4,440 are in Minnesota and 12,000 in Ontario. The two most important sources of supply from Minnesota are the waters of the Vermilion river and those of the international boundary chain of lakes. This latter source brings water from both sides of the boundary line for a distance of 150 miles to the east-southeast of Kettle falls, *i. e.*, from the divide between the lake Superior and the Hudson bay drainage in T. 65–2 W., Cook county (between North and South lakes). Rainy lake, whose drainage basin is equal to nearly one-fifth of the area of the state of Minnesota, discharges its waters through the Rainy river. This begins at the outlet of the lake in sec. 25, T. 71–24, a locality known as Koochiching by the Indians. Here are two small rapids, with a fall of three feet, beyond which the river flows westward as a stream 600 to 1,200 feet in width to the Lake of the

*Report on the geology of the Rainy Lake region. *Geol. and Nat. Hist. Survey of Canada*, Annual Report for 1887–'88, new series, vol. iii, pp. 1 F–182 F. pls. 12–19, 1889. Accompanied by a geological map.

† Report of observations made during the summer of 1887. *Geol. and Nat. Hist. Survey of Minn.*, Sixteenth (1887) Annual Report, pp. 395–478, 1888. Accompanied by a geological map.

‡ Since this report was published the Ontario Bureau of Mines has issued reports on the Rainy Lake region, as follows:

A. P. Coleman. Gold in Ontario: its associated rocks and minerals. *Fourth Report of the Bureau of Mines of Ontario*, pp. 35–100, 1895; with maps.

A. P. Coleman. Second report on the gold fields of western Ontario. *Fifth Report of the Bureau of Mines of Ontario*, pp. 47–106, 1896; with maps.

Archibald Blue. A tour of inspection in northwestern Ontario. *Ibid.* pp. 107–190.

Woods, and from thence the waters find their way into Hudson bay. Two and a half miles west of the outlet are the Koochiching falls, where the river plunges over a ledge of rock twenty-one to twenty-four and a half feet high at different stages of water in the river. (See plate O, figure 2.) It is estimated that there are 12,000 cubic feet of water flowing out of Rainy lake every second.

The altitude of Rainy lake has been definitely determined as 1,111 feet above sea level. The greatest known depth of the lake is at a place about six miles north-northwest of the Brulé narrows, where there is the lowest depression in the region, or a depth of water of 110 feet, while the average depth of the lake is probably not far from forty-seven feet.* The accompanying table gives the hights in feet above the sea level of some of the lakes in this vicinity and to the southward. Those marked by an asterisk are accurately determined.

	Feet.
Rainy lake,	*1,111
Kabetogama lake,	*1,121
Namekan lake,	*1,121
Sand Point lake,	*1,121
Crane lake,	*1,121
Little Vermilion lake†	*1,121
Basswood (Bassimenan) lake,	*1,300
Vermilion lake,	*1,357-1,360
Lake Superior,	*601.56

The Rainy Lake district is of the nature of a plateau with a very gentle slope from all directions, except the west, toward the lake. This plateau, while not having a perfectly even surface, still is not broken by any considerable elevations or depressions, and altogether has a decided flatness. The immediate shores of the lake usually do not rise more than fifty feet above the water, and land 100 feet higher than the lake surface is not common. The highest land in the Minnesota part of this district is just to the south of Kabetogama lake, and the highest elevation in the area mapped is between Open Water narrows and Bear's passage, where a ridge rises about 275 feet above the lake level, or about 1,400 feet above the level of the sea. The lowest depression has already been mentioned, 110 feet below the surface of the lake, or 1,001 feet above the sea. The average elevation of the land is probably not more than sixty feet higher than the lake, or 1,171 feet above the sea. A number of soundings made by Dr. A. C. Lawson show that the general level of the lake bottom is about as much below the surface of the water as the adjacent land is above it; consequently if land and water areas were in equal amounts, the general level of the plateau would be nearly that of the surface of the lake. But, as the land surface much exceeds the water, the average elevation is some feet above the lake level; and it is estimated that the average elevation of the plateau in the area shown on the geological map (plate N) is approximately 1,150 feet above the sea, or about 500 feet higher than lake Superior.

The remarkable general flatness of the district is well shown by the large area penetrated by water that stands at nearly the same level. Rainy lake itself, with an extent of forty-six miles east and west and thirty-three miles north and south, may be said to extend through a rectangular area of these dimensions; thus its waters are spread out in various parts of a district including 1,500 square miles, and the general elevation of this rectangular district is not many feet above the lake surface. While just to the south and southeast is a series of lakes, including Kabetogama, Namekan, Sand Point, Crane and Little Vermilion lakes, which have an area probably half as large as Rainy lake and which stand at a level only ten feet higher.

This plateau-like nature of the district will be again referred to in the outline of the geological history of the region, and a possible explanation of the present topography will be suggested.

In its general appearance this district is characteristic of much of northeastern Minnesota; it is a country of lakes, swamps, and timbered rocky knolls. The surface, especially in the district here reported on, is not truly hilly, but mammillated or hummocky. The small knolls that rise above the level of the lakes and swamps are glacially rounded and are covered with only a scant soil, which, however, supports quite a luxuriant growth of pines, spruces, balsam fir, white birch and poplar. The shores of Rainy lake are generally rocky, but toward the western end sand beaches are frequently seen, and the heads of the bays are usually marshy or swampy. Over large tracts there are practically no surface deposits of glacial or more recent origin, the rocks coming to the surface whenever the thin forest soil is pushed aside. The surface is dotted with numerous lakes and lakelets varying in size from an acre to bodies of water a hundred or more square miles in extent. The lakes are largely in completely rock-bound basins and most of them are elongated in a direction parallel to the trend of the country rocks. From one rocky basin a short, rapid stream carries the water of one lake down to the next lower basin, and in this way the greater part of the drainage is accomplished. Aside from these streams there are over large areas none of any importance and nothing that can be called a river, but wherever the rocks are covered with considerable quantities of drift the lakes become scarcer and the drainage is carried on by the ordinary rivers and smaller streams. The outlets of the lakes are so narrow that, after the melting of the snows and after the early spring rains, the waters are partially dammed back and held at a level four or five, or even ten feet higher than normally.

At the west end of Rainy lake this surface of lake and rock suddenly gives way to a plain of clays, through which the underlying rock rarely emerges. The change from the rocky lake country to this clay plain is abrupt

*A. C. Lawson. *Op. cit.*, pp. 13 F, 16 F.

†Kabetogama and Namekan lakes seem to be at exactly the same level. Namekan lake is a little below Sand Point lake, and the latter is a little lower than Crane and Little Vermilion lakes.

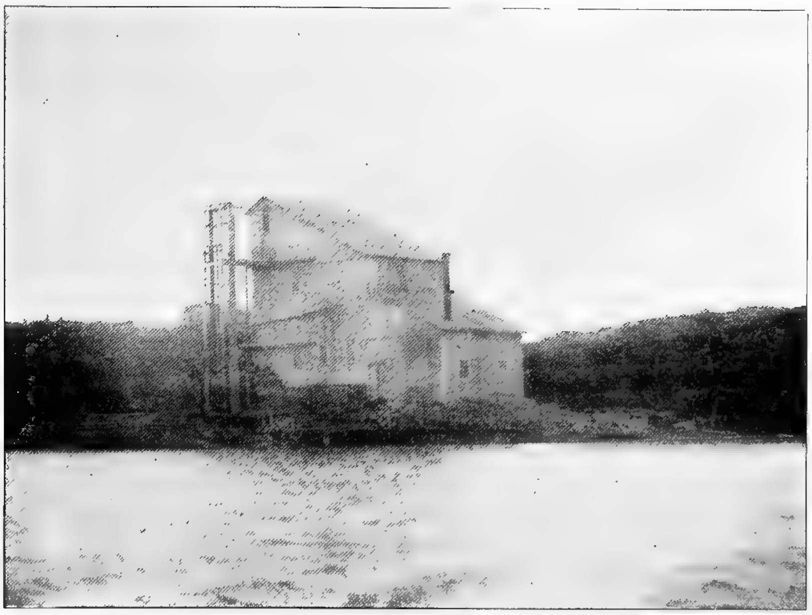

FIG. 1. THE FIRST STAMP MILL AT RAINY LAKE. ERECTED FOR THE LITTLE AMERICAN MINE. (p. 205.)

FIG. 2. HEAD OF KOOCHICHING FALLS IN THE RAINY RIVER, LOW WATER. FORT FRANCES, ONTARIO, IN THE BACKGROUND. (p. 194.)

and very striking, and is intensified by an equally sudden change in the flora; the lake shores and the country to the east have a forest largely of evergreens and boreal in its aspect, while to the west of the lake a forest largely deciduous and more southern in its character appears. The extremely flat surface of the plain is, as far as altitude is concerned, a continuation of the rocky plateau to the east; it has a gentle slope to the west and is unvaried by lakes or other features except the shallow, steep-sided trenches cut by the Rainy river and its tributaries.

II. GEOLOGY.

The rocks underlying this district are among the most ancient known. To a considerable extent they are completely crystalline, and, while many of them bear evidence of having been deposited in water as true sediments, still they offer no trace of any fossils and are regarded by some geologists as older than the earliest life on the globe. From the flat position, in which these strata were originally deposited, they have been elevated, folded and crumpled so that now they stand in abnormal attitudes; and in addition to the mountain-making forces to which these rocks have been subjected, they have been intruded by vast masses of granitic rock. Thus it is difficult to decipher the exact structure of the region. Another cause of this difficulty is the almost universal development, except in some of the granitic rocks, of parallel schistose structures, which are easily mistaken for sedimentary planes and which are not always parallel to these planes, although as a rule in this district the schistose structure coincides in direction with the bedding. The general strike of the rocks is from east and west to east-northeast and west-southwest, but outside of the area shown on the geological map the strike varies much, the rule being that it follows around the outlines of the great granite-gneiss masses of the region.

In age, all of these rocks, with possibly the exception of the diabase dikes whose exact age is unknown, are pre-Cambrian. They are readily separable into four distinct groups. Beginning with the lowest these are: (1) Laurentian, composed of granites and granitoid gneisses and allied rocks; (2) Coutchiching, composed of mica schists grading into fine grained gneisses; (3) Keewatin, composed of hornblendic, greenish and sericitic schists, conglomerates, graywackes, etc.; (4) Diabase dikes, more recent than and cutting all the others. The following table will show the position of these rocks at the base of the geological column, their equivalents in the country to the southeast of Rainy lake and their designations in the terms used by the Geological and Natural History Survey of Minnesota. In the nomenclature of the U. S. Geol. Survey the Keewatin and Coutchiching belong to the Algonkian, and the Laurentian to the Archean or Basement Complex. In the table the uppermost or more recent rocks are placed at the top.

<table>
<tr><th colspan="3">Geological Names.</th><th>Rainy Lake Disrict.</th><th>Equivalents to the Southeast.</th></tr>
<tr><td rowspan="2">PALEOZOIC</td><td rowspan="2">Taconic.</td><td>Keweenawan.</td><td>Diabase dikes(?)</td><td>Copper-bearing rocks of lake Superior.</td></tr>
<tr><td>Animikie.</td><td>(Wanting.)</td><td>Iron ores and other rocks of the Mesabi range.</td></tr>
<tr><td rowspan="3">ARCHEAN.</td><td rowspan="2">Ontarian.</td><td>Keewatin.</td><td>Green and sericitic schists, conglomerates, graywackes, etc.</td><td>Iron ores and other rocks of the Vermilion range.</td></tr>
<tr><td>Coutchiching.</td><td>Mica schists.</td><td>Crystalline schists on both sides of the Vermilion range (?)</td></tr>
<tr><td colspan="2">Laurentian including Eruptives.</td><td>Granites and gneisses.</td><td>Granite and gneisses of Vermilion and Basswood lakes.</td></tr>
</table>

The Rainy lake district has no solidified rocks more recent than these ancient Archean ones, but scattered over the surface are small deposits of glacial drift, and just west of the lake, as has already been mentioned, is a considerable thickness of clays.

*The Laurentian.** The Laurentian is composed entirely of completely crystalline rocks, granites and syenites with gneisses of the same mineralogical composition. The extent of territory covered by such rocks in northern Minnesota and adjacent portions of Ontario is surprisingly great. Nearly a third of the region here reported on is underlain by the Laurentian, while all the shores of Rainy lake north of the area shown on the geological map are composed entirely of these same rocks. Contrary to expectation, these hard granitic rocks do not always form pronounced hill ranges, as is the case with the Giant's range of granitic hills on the northern flank of the Mesabi iron range, but very frequently these areas of Laurentian rock give a comparatively level surface on which are extensive and extremely irregularly outlined bodies of water. Examples of these spider-like lakes

*In this report the term *Laurentian* is used to include all the gneissic and granitic rocks of the Archean in this region. That many of these rocks are of later date than, and intrusive into, parts of the Coutchiching and Keewatin, is well known; but, as such rocks have generally been mapped and described as Laurentian in the previous reports of the Minnesota survey, and as they have been also described under this term by Lawson in his well known writings on the geology of that part of Ontario lying immediately to the north of Minnesota, and as such rocks are generally known as Laurentian, the writers have thought best to retain this term in the present report, even though this usage is, in part at least, a violation of the idea of Laurentian used strictly as an age term.

stretching over considerable areas of granite can be seen in Saganaga, Basswood (Bassimenan) and Crooked lakes, and in Lac la Croix and a large portion of Rainy lake itself.

In color the Laurentian rocks are white, gray, pinkish and reddish, the prevailing color in any one place being largely due to the color of the most important mineral,—the feldspar. In grain these rocks vary from those in which the individual minerals can scarcely be recognized with the naked eye, to very coarse aggregates where some of the feldspar crystals are several inches across. Most of these rocks can be called granites, *i. e.*, they are granular aggregates of quartz and feldspar with a dark mineral, either black mica (biotite) hornblende or augite. Sometimes two of these are present, and in other places, especially in the coarse grained dikes or veins which occur in the mica schists, white mica (muscovite) is the only mineral present in addition to the quartz and feldspar. The quartz frequently diminishes in quantity and even completely disappears; such a rock with no quartz, or a very small amount of it, is known as syenyte. In fact all the minerals vary greatly in amount in the different parts of one rock mass. For example, a rock in a certain place composed of quartz, feldspar and hornblende will vary by a gradual decrease of the hornblende until almost none is left, and we have a rock composed almost entirely of quartz and feldspar; or, as the hornblende decreases, mica or augite may increase and we have a change from a hornblende granite to a mica or an augite granite. The only mineral which is prevalent throughout the whole of the Laurentian is feldspar, and even this varies greatly in amount within small distances.

In structure, also, the Laurentian rocks differ considerably. The granites and syenytes are sometimes massive in appearance, *i. e.*, they exhibit no schistose or laminated structures; the structure is granular, and every part of an exposure is like every other part, except perhaps as regards the relative proportions of the different minerals or the fineness of the grain. But this massive appearance is by no means prevalent throughout the whole region; it generally gives place to a somewhat schistose or foliated structure. Some of the minerals of the granite or syenyte are often seen elongated or flattened in one direction; this is especially true of the mica. When this is the case the rock breaks more easily along the planes in which these crystals lie. Or the rocks may be crossed by narrow streaks which are composed largely of one mineral with the longer diameters of many of the crystals lying roughly parallel. At other times certain bands, one to three or more inches wide, will be seen running through the rock, each band being of a somewhat different composition or texture from the adjoining ones. These foliated and banded rocks are known as gneisses, and in this region they can be conveniently designated as granite gneiss or syenyte gneiss, depending upon whether the mineralogical composition is similar to that of granite or syenyte. These various features of the Laurentian rocks allow them to be separated into different classes or groups both mineralogically and structurally, but these groups are frequently seen grading into each other. The hornblende granite of one point will pass gradually into a hornblende syenyte near by, and this again may change to a mica syenyte. Again, a perfectly massive rock will become foliated within a short distance, the intervening steps between the massive and the foliated or gneissic rock being readily traceable. It thus is often impossible to draw a line between the various phases of these Laurentian rocks; consequently in the geological map no attempt has been made to separate the different varieties. It is unnecessary to describe all the outcrops of these rocks, or to indicate the areas occupied by each of the different groups, but a brief account of a few of the more interesting or typical occurrences will be given below.

At Koochiching falls the rock is a medium gray biotite syenyte; the component minerals are white feldspar and biotite, with a little hornblende and epidote. This syenyte is massive in some places, but usually shows a slight indication of a foliated or gneissic structure, thus approaching a biotite syenyte gneiss. It contains many darker masses, sometimes a foot or more in diameter; they are composed of the same minerals as the main part of the rock, but the mica makes up a very large proportion of each dark mass. These darker masses can be referred to fragments of foreign rock included in the syenyte, or to segregations of the basic minerals of the syenyte itself. This medium grained gray biotite syenyte is the usual phase of the rock at the falls. It is especially well shown in the rocks thrown out from an excavation for a canal at Fort Frances made by the Canadian government some years ago. Below the falls the rock becomes porphyritic with crystals of flesh colored feldspar which are often an inch in length. These crystals stand out all over the weathered surfaces of the rock. Two islands about three-fourths of a mile below the falls contain excellent exposures of this rock; the upper of these islands is composed of syenyte alone, while the lower also shows a fine micaceous schist, which, in places, is seen in sharp contact with the syenyte; and in other places there is apparently a transition from the syenyte to the mica schist within a distance of a few feet.* Along the river above the falls on the Canadian side no outcrops were seen, but two exposures of the syenite occur on the Minnesota side; the first of these is in the town of Koochiching about where the north line of sec. 34, T. 71-24, cuts the shore, and the second is near the centre of the N. ½ of N. W. ¼ sec. 35, T. 71-24. At the latter outcrop the rock is porphyritic with feldspar crystals, most of which are bright red in color, while a few are greenish.

In the N. E. ¼ of sec. 28, T. 71-23, in Rainy lake, is an island elongated in a north and south direction, while just a few yards to the southwest is another and smaller island on which the usual relations of the mica schist and the granite are clearly and unmistakably shown. The latter rock forms the northeast side of this little island and the former the southwest side; along the centre of the island the two are in contact. The granite is a light gray rock of medium grain, composed of white feldspar, which is probably largely orthoclase, quartz and biotite. There is sometimes a sub-porphyritic aspect due to the existence of a few crystals of feldspar larger than the other crystals of the rock. There is also an indication of a foliated structure caused by an indistinct streaming of the biotite and an elongation of some of the feldspars in one direction. This is not pronounced enough to strictly allow the application of the term gneiss, and the rock may be called simply a granite,

*Seventeenth (1887) *Ann. Rept. Geol. and Nat. Hist. Survey of Minn.*, pp. 410-412, 1888. See also A. N. WINCHELL. The Koochiching granite, *Am. Geol.*, vol. xx, pp. 293-299, 1897.

or a gneissic or gneissoid granite if it is desired to make the existence of an indistinct foliation prominent. This partial foliation agrees in strike and dip with the mica schist which stands nearly vertical and trends 50° to 60° east of north. At the contact line, which roughly follows the direction of the strike, the granite is not particularly finer grained, nor does it differ otherwise from its normal condition. A few angular fragments of mica schist are to be seen entirely surrounded by the granite, and in the mica schist are irregular vein-like forms or dikes running both across and along the beds of mica schist; some of these dikes can be traced directly into the main mass of granite. They are of all sizes from a fraction of an inch to several feet in width. A hand specimen collected to illustrate the contact shows a small stringer of granite, one-fourth of an inch wide, which starts out from the main mass of the granite, runs for two inches in the mica schist and then gradually thins out and disappears. The relations of these two rocks show conclusively that the granite here acts as an eruptive rock and that it has been forced, while in a plastic or fluid state, into cracks or fissures in the mica schist. At the contact the mica schist does not appear much different from the same rock a short distance away, but it is harder and less schistose, and microscopical examination would probably show some mineralogical changes due to the heat of the granite. Another interesting feature on this small island is the occurrence of small dikes of a finer grained rock which cuts the granite itself and is therefore of later date. This rock is a very fine-grained white granite composed almost entirely of quartz and feldspar; it cuts the main granite in numerous small dikes which are two feet or less in width. These dikes are not finer grained at the edges than at the centres, and they do not exhibit any foliation; there is nothing to show definitely how much later these dikes are than the main mass of the granite, but it is probable that the two rocks do not differ much in age. One dike of this fine-grained white granite (or aplyte) was seen in the mica schist.

Three-fourths of a mile east of these islands, on the blunt point near the centre of the north side of sec. 27, T. 71–23, the granite and mica schist are again seen in contact. Here the granite exists commonly in thick bed-like forms between the layers of mica schist, but in many places these "beds" are seen to be directly continuous with other masses of granite that cut directly across the beds of mica schist. The contact of these two rocks can also be seen on the island in the S. E. ¼ sec. 22, T. 71–23.

It is not uncommon to find in the mica schists large veins or dikes of very coarse-grained rock of a composition similar to the granites. In such places the individual crystals often reach a length of several inches. The minerals of these coarse-grained rocks are feldspar, which is usually pinkish or reddish and is either orthoclase or microcline, quartz, and most commonly muscovite. The quartz and feldspar are often grown together in such a manner as to form graphic granite, *i. e.*, a certain large mass of feldspar, which is shown to be all one crystal by the extension of the same cleavage plane through it, is spotted all over by smaller grains of quartz; and each quartz grain, when studied under the microscope, is seen to have the same crystallographic axis as the other grains in the same feldspar crystal, showing that these grains are really all parts of the same quartz crystal. Perhaps a good illustration of this growing together or interpenetration of feldspar and quartz can be had by likening the feldspar crystal to a sponge full of cavities, which cavities have all been filled by a continuous mass of quartz. Rocks of this nature are quite common along the shores of Kabetogama lake, and to the south and east along the international boundary. The individual crystals of feldspar often reach surprising dimensions. For instance, in one place a crystal was seen which measured actually thirty-three inches in length, and many were found over a foot long. The locality where this large crystal occurs is on the point which is at the centre of the W. ½ of S. E. ¼ sec. 19, T. 70–18, on the south shore of the eastern arm of Rainy lake. Here this coarse-grained rock, which is often known as pegmatyte, forms large veins or dikes in the mica schist. Sometimes these pegmatyte forms occur in the granite itself.

A short distance northwest of Shoal lake are gold-bearing veins in an area which has been mapped as granite. The rock in which the veins occur is somewhat different from that seen elsewhere, and, as it has been called by various names, we have endeavored to make a rather careful examination of the specimens we have of this rock in order to determine, if possible, just what the rock is. As just stated, this rock has been called granite, and there are areas in the midst of the rock which hold the veins that are true granite, and which do not seem to be sharply separated from the vein-holding rock. A description of a specimen from one of these granitic areas on Wiegand's location, A L 75, is as follows:

Macroscopically this rock is a gray granite of medium grain, and quite fresh. The minerals are quartz, feldspar and biotite; the first two are in approximately equal amounts and compose three-fourths to five-sixths of the rock. The feldspar is whitish, varying to greenish and pinkish, the latter shade apparently due to iron staining.

Under the microscope the structure of the rock is seen to be truly granitic. In addition to the minerals mentioned above are small flakes of muscovite and a few greenish areas composed of chlorite. The quartz is ordinary granitic quartz containing bubbles and gas cavities. It shows undulatory extinction, and frequently a large grain has been fissured into many smaller ones which, however, have not been separated from each other and so extinguish at almost the same time. Undulatory extinction and this fracturing of the grains are the effects of pressure on the quartz, which mineral is one of the first to show the effects of having been subjected to pressure, especially when enclosed in a hard, solid substance like granite. The feldspar is highly altered, largely to a mass of brightly polarizing flakes and fibres, which seem to be muscovite. In some grains a trace of polysynthetic twinning still remains, and undulatory extinction is present. The feldspar was originally orthoclase and an acid plagioclase apparently of the albite-oligoclase series.

To sum up, this rock is a typical medium grained biotite granite, or granityte, with the feldspar considerably altered; the rock has been subjected to pressure, as shown by the fracturing of the quartz and the

undulatory extinction of both quartz and feldspar, but no schistose structure can be seen either in the hand specimen or in the slide.

The rock in which the veins occur at Wiegand's location, A L 75, is a peculiar greenish gray rock composed of quartz grains imbedded in yellowish green ground mass. The quartz is in glassy grains of all sizes up to those one-fourth of an inch across; some of the grains are pinkish, due to iron staining. The ground mass is too fine-grained to allow its constituents to be distinguished by the naked eye; it appears homogeneous, is soft, has a greasy feel, can be readily scratched with a knife and effervesces slightly with cold hydrochloric acid. A slight schistose structure can be distinguished in the ground mass. A few grains of pyrite occur, but fully a third of the rock is quartz.

The thin section shows a number of quartz grains of various shapes and sizes imbedded in a ground mass of minute fibres. The quartz shows undulatory extinction and fissuring to a better degree than in the granite just described. A few small flakes of muscovite are present, also a small amount of calcite and an opaque yellowish substance. The fibres of the ground mass are quite small and polarize in rather bright colors; they are muscovite or sericite. Mixed in with the fibres are very minute grains of quartz and perhaps also some of feldspar. At places in the ground mass are irregular areas and shreds of feldspar; often these have a few flakes of mica in them and their edges are jagged, due to a penetration of the fibres into the feldspar substance. Frequently several areas of feldspar in the same vicinity extinguish together, showing that they are remnants of an originally larger grain which has passed almost completely into mica. The fibres of the ground mass are often elongated in one direction; this causes the schistose structure of the rock.

As to just what this rock was originally it is hard to make a positive statement. That it has been subjected to pressure and shearing is evident from the condition of the quartz and the schistose structure of the rock. It is also evident that some parts, at least, of the ground mass are due to a breaking down of feldspar grains, the remnants of which are still present; it is not improbable that most of the ground mass has a like origin. While all the field relations of this rock are not known, still it occurs in an area of rock in which are parts that are certainly granite, as that just described, and it does not seem to be sharply separated from these certainly granitic areas. The quartz grains are very similar to those in the granite above described. Thus it seems possible, and indeed probable, that the rock under consideration was originally a granite, and that it has been subjected to pressure and shearing, which have induced the schistose structure, and which, with the aid of percolating waters and perhaps heat also, altered the original minerals (excepting the quartz) to the present fibrous ground mass. The quartz shows fracturing and undulatory extinction, but is otherwise unaltered, as it is almost indestructible when compared with the other minerals of the granite. That the rock might have been other than a granite it is impossible at present to deny; there are, however, no characters that necessarily indicate another origin. The original nature of the rock can be determined only by a careful investigation of the field relations supplemented by microscopic evidence. But from our present knowledge we would consider this rock as most probably an altered phase of granite.

The exact nature and origin of these Laurentian completely crystalline rocks in the Rainy Lake region and elsewhere are rather complicated questions and cannot yet be settled to the satisfaction of all who have studied them. That these rocks in the region here considered are now totally lacking in characters that clearly show them to have once been clastic like ordinary sediments goes without saying. And there is no positive proof that the more pronounced gneisses,—those that show alternations of bands of different mineralogical or structural characters, which varieties of gneiss are not common,—were once sedimentary, although the presence of this banding and other less pronounced foliation is to some a strong argument for an originally sedimentary nature. That these granitic rocks are intrusive in numerous places into the Coutchiching mica schists, and often into the Keewatin rocks, is absolutely certain. Good proof of the metamorphism of the clastic rocks of the region to form gneisses has not yet been observed, although places that show this may be found in the future. Dr. A. C. Lawson, who is familiar with this region, thinks that these Laurentian rocks represent older rocks than the Coutchiching, but whether originally sedimentary or not is only to be guessed at; they have been softened and fused and while in this condition have been intruded into the rocks lying above them and there solidified. The following quotation from this author will help to explain his view:

"This group of crystalline rocks, granites and syenytes, foliated and non-foliated, forms the floor of the region upon which rest all other formations that are not in the condition of dikes or intrusive bosses. Regarded as a geological system of rocks it occupies an apparently paradoxical and anomalous place in any scheme of classification. As the floor or basis upon which the geological column of stratiform rock rests, it must be regarded as the first or fundamental system of rocks of which we have any cognizance. If, however, we inquire as to the age of these rocks, we are forced, by the direct application of the simplest principles of geological science, to look upon them as of later age than certain of the series which overlie them. We do not yet know their original condition prior to the fusion from which they solidified into granites, syenytes and gneisses. They may have been sedimentary; they may have been the original crust of the earth. The abstract speculations that are so often indulged in on this and similar questions have not decided the facts of the matter. There is yet no sufficient ground for a just opinion upon it. But whatever may have been that original condition the evidence is clear on this point, viz.: that the fusion and solidification, whereby they were brought into their present condition as firm-crystalline rocks, took place at a period subsequent to the existence, in a hard, brittle condition, of the stratiform and often very distinctly clastic rocks which occupy a higher place in the column. Therefore, as rocks, the members of this fundamental system are of younger age than that of the nearest overlying formations. An analogous case with which every geologist is familiar is that of dikes. These are of younger age

than the strata they cut, although the main mass, of which they are merely the apophyses, is far inferior to those strata and may form the base upon which they rest."*

Under this view, concerning the Laurentian, the floor on which the Coutchiching rocks, and in some places the Keewatin, were deposited is now entirely unrecognizable; it has been softened and moved so that its relation to the Couchiching is now an eruptive one. On the other hand, it seems probable that parts of this old floor are still preserved; such places, however, have not yet been found in this locality, all the granite and gneiss areas examined apparently showing an eruptive relation to the Coutchiching; and the same can be said of the relations of the granite and gneiss to the Keewatin. However, to the northeast of Rainy lake rocks apparently corresponding to the Keewatin have been found unconformable upon an older series of granites and gneisses† supposed to represent the Laurentian; and it is not impossible that the Keewatin conglomerate seen on the north of Shoal lake will be found to be unconformable on the granite to the north. Many problems concerning these ancient rocks,—Laurentian, Coutchiching and Keewatin,—especially as regards their relations to each other, are still unsolved, and it will not be profitable to discuss them further here.

The Coutchiching. This series of rocks, while occupying a large amount of territory, is of comparatively simple character and will need but a brief description. They extend along the south shore of Rainy lake from the outlet east to Jackfish bay, then for a distance of eight miles (to the line between Itasca and St. Louis counties) the Keewatin occupies the shore, but all the south shore east of this and all the shores of the eastern arm of the lake, with the exception of a few granite areas, lie entirely in rocks of this series. Other small areas are found to the north of the belt of Keewatin rocks that runs east-northeast from Jackfish bay.

Lithologically the Coutchiching is preëminently a mica schist formation; with the mica, which is mostly biotite, is either quartz or feldspar, and commonly both in the more coarsely crystallized facies. The rocks near the outlet of Rainy lake are mostly quite fine grained mica schists or even gray to brownish mica slates, but usually the Coutchiching rock is a well defined mica schist. In close proximity to some of the granite masses, as along the north shore of Kabetogama lake, the mica schist becomes quite coarsely crystallized and might properly be called a gneiss, but it is not easily confounded with the gneisses of the Laurentian. In addition to the usual minerals, others, such as garnet and staurolite, are sometimes found in the mica schists not far from their contact with masses of granite. The schistose structure, due to an arrangement of the mica scales in roughly parallel positions, is characteristic of this series. In many places there are rapid alternations of bands, from an inch to several feet in width, of slightly different mineralogical composition, structure or color; the position of these bands gives the strike and dip of the rock, and where they are lacking the schistose structure is taken to indicate the strike and dip, as this structure seems to be parallel with the banding wherever the two are seen together. There is a vast thickness of this monotonous mica schist formation along the eastern arm of Rainy lake and to the southward; several estimates by Dr. A. C. Lawson show an apparent thickness of about five miles.‡ These Coutchiching rocks in several particulars appear so much like ordinary sediments that it seems necessary to consider them as sedimentary beds which have been more or less recrystallized *in situ* by metamorphic processes. This change has been largely in the nature of regional metamorphism, but the more coarsely crystalline condition of the beds in close proximity to intrusive masses of granite shows that contact metamorphism has also played an important part.

The relation of the Coutchiching to the Laurentian has already been mentioned. Its relation to the Keewatin is not definitely known. The Coutchiching, however, is lithologically quite distinct from the overlying Keewatin rocks, and in the field it is a comparatively easy task to separate these two series of rocks. Where they are in contact, however, they have the same strike and dip and thus appear strictly conformable. But the difference in lithology between the Coutchiching and Keewatin is marked; in the former we have no evidence of volcanic activity, while in the latter there are numerous proofs of great volcanic activity, in fact, the Keewatin can be said to be characterized as a period of intense and wide-spread eruptions. Moreover, in the Keewatin are conglomerates, which, in places, seem to be basal beds resting on the Coutchiching. Lawson§ has consequently inferred an unconformity between these two series, and while the existence of this is not undoubtedly proven, it still seems quite probable.

The Keewatin. This series of rocks is more varied in lithology than either of the others just described, and it is of more interest on this account, and also because in it are found many of the gold-bearing veins thus far discovered. The rocks are conglomerates, slates, sericitic, chloritic and hornblendic schists, agglomerates, graywackes, and more or less altered igneous rocks, both acid and basic. The presence of large amounts of hornblendic and other green schists, some of which are clearly of igneous origin, gives to this rock series a prevalent green color, and this abundance of "greenstones" and "green schists" is one of the most characteristic and distinctive features of the Keewatin series. That parts of these green rocks represent ancient igneous ejections, both lavas and ash beds, is absolutely certain; and, as before stated, they show that the Keewatin was a time of violent and extensive volcanic activity. But the Keewatin was also a time of deposition for ordinary sediments. Much of the fragmental volcanic material seems to have been deposited in water, which has given a stratiform character to the beds, and mixed with this fragmental igneous matter was more or less of ordinary sediments; the two kinds of deposits evidently grade into each other, the igneous material predominating in close proximity to volcanic vents. These Keewatin rocks, like the other series, have participated in great earth move-

*Amer. Jour. Sci., 3d series, vol. xxiii, pp. 474-475, 1887.

†H. L. Smyth. Structural geology of Steep Rock lake, Ontario; *Amer. Jour. Sci.*, 3, vol. xlii, pp. 317-331, pl. 11, 1891.

‡*Geol. and Nat. Hist. Survey of Canada*, new series, vol. iii, pp. 101-102 F. 1889.

§ *Op. cit.*

ments, which have produced slaty and schistose structures. The effects of these movements seem to have been better registered in the Keewatin rocks than elsewhere by a more pronounced and almost universally present schistose cleavage.

The most important belt of Keewatin rocks is that which is first seen on the south shore of Rainy lake at Jackfish bay. West of here this belt has not been carefully traced out, but a few outcrops have been seen, some of which will be mentioned below. East of this bay the Keewatin forms the south shore of the line between Itasca and St. Louis counties; and a number of islands just to the north of the shore, the largest of which are Grassy, Grindstone, Dryweed and Sand Point, are mostly composed of the same rocks. This belt of Keewatin runs a little north of east, crosses the lake, and extends past Seine bay, and Shoal and Bad Vermilion lakes and eastward beyond the limits of the map.

To the west of Jackfish bay sections were made south from Rainy river in two places. The first was along the west line of sec. 35, T. 71–24, and southward for a mile and a half beyond the south line of this section. No outcrops were seen; the ground passed over is nearly level and forms a part of the clay plain which lies along the river. However, in the S. E. ¼ of S. W. ¼ of this same section there is an exposure of considerable extent, which rises a few feet above the level of the plain. The rock is a fine-grained gray sericitic schist or slate with no pronounced lines of sedimentation. The cleavage, as measured in three places, runs N. 50° E. (mag.) and stands about vertical. Parallel with the cleavage are fine laminæ which, in the absence of more definite indications, are assumed to represent the true sedimentary planes of the rock. The second section was made from the lake shore at the outlet, along the east line of range 24, to a point half a mile south of the southeast corner of T. 71–24. Several outcrops were crossed, all of which present a schistose cleavage that runs N. about 50° E. (mag.) and dips at a high angle toward the northwest. In some places a distinct alternation of beds of different composition was seen; these give the true strike of the rock which, as far as seen, coincides with the cleavage. The rock of these outcrops is largely a sericitic schist, but it frequently becomes darker colored and greenish, and contains minute laminæ of white siliceous material.

On the south shore of Jackfish bay and on an island in this bay near the west line of sec. 26, T. 71–23, are excellent exposures of conglomerate. The conglomerate of this island, which is made entirely of this rock, has as a matrix a greenish to grayish fine-grained schistose rock composed of silvery micaceous scales and other material which is too finely divided for recognition by the naked eye. In some places the matrix becomes coarser and is crowded with quartz grains the size of a pin's head and larger. The pebbles of the conglomerate are very numerous and are well distributed throughout the rock of the island; they vary in size from pieces the size of a pea to those that are ten inches across. Several kinds of rock are represented in these pebbles, but the most common is white or yellowish vein quartz; next in abundance are pebbles of a gray rock which seems to be a very fine-grained granite. Pebbles more or less similar to the matrix are also common; these are not easily recognized on fresh fractures, but on weathered surfaces they are quite readily distinguished. The pebbles are mostly well rounded; this is especially true of those composed of quartz which are very sharply separated from the matrix and can be easily dislodged. The conglomerate has been subjected to shearing and stretching and as a result the pebbles are commonly seen flattened in one plane, which coincides in direction with the schistose cleavage of the matrix. The strike of this cleavage is N. 60–65° E. (mag.) and the dip is about vertical. In a few places there are some indications that the true strike of the conglomerate is almost at right angles to the strike of the cleavage; these indications, however, are not entirely satisfactory evidence of the position of the bedding, nor is there satisfactory evidence that the true strike is parallel with the cleavage. On the south shore of this bay are other outcrops of the conglomerate, the matrix at this place being a green schist. Small pebbles are not common here, most of those seen being over six inches in diameter; sometimes they reach a size of three feet in greatest diameter. These boulders are largely of one rock—a rather fine-grained greenish to pinkish biotite granite. They are well rounded and lie with their long axes parallel with the strike, which is here plainly coincident with the schistose cleavage.

Other exposures of conglomerate occur to the east of Jackfish bay on the south shore in the N. ½ of sec. 31 and the S. ½ of sec. 30, T. 71–22. Here the matrix is a green hornblende schist, more or less siliceous. The pebbles are mostly of about the same nature as the matrix and are distinguishable only on weathered surfaces. They have been elongated in a direction parallel with the cleavage, and on this account and also because they so closely resemble the matrix it is hard to tell whether they originally possessed rounded outlines or not. However, a few boulders occur at this place, which are of rock similar to the granitic boulders in the exposures on Jackfish bay, and they are distinctly and smoothly rounded.

On the south shore of Dryweed island in sec. 25, T. 71–22, the rock of the island, which is a sericitic schist, becomes conglomeratic with granitic boulders similar to those just mentioned.

Another belt of conglomerate is seen along the north side of Grassy and Shoal lakes. The specimens we have of this show the matrix to be a rough green hornblendic schist, sometimes quite rich in large and small grains of quartz. The pebbles are of greenstone, black and red jasper, quartz and felsyte, many of them being well rounded. Just northwest of Shoal lake this conglomerate is found resting directly upon the granite mass of Bad Vermilion lake. The exact contact line is exposed for some distance, and small patches of the conglomerate, which are easily dislodged, are found lying directly on the surface of the granite. Although a casual examination failed to find any pebbles in the conglomerate that could be certainly referred to the underlying granite, still the relations of the two rocks at this place seem to indicate that the conglomerate is unconformable on the granite.

Another typical rock of the Keewatin series is seen in the S. ½ of sec. 29, T. 71–22. The conglomerate to the west of this gradually loses its greenish character and becomes lighter colored and silicious on going east-

ward; at the same time the boulders become less numerous and finally disappear altogether, and we have a rock that is fine-grained, hard, tough, siliceous, and silvery gray in color. This rock forms bare, rounded knobs in sec. 29, and is quite massive in appearance. It continues eastward to form Grindstone and Dryweed islands, but on these islands, especially the latter, it becomes softer and more schistose, forming a siliceous sericitic schist. It also in places shows evidences of bedding which is parallel with the schistose structure, and, as mentioned above, it becomes conglomerate on the south shore of Dryweed island in sec. 25, T. 71 22.

Just to the south of this belt of siliceous sericitic schist lies a belt of greenish schists, which are of interest for the reason that in them are found the veins that have been most exploited for gold. This belt of rock comes to the shore in the N. E. ¼ of N. W. ¼ of sec. 32, T. 71–22, and continues eastward forming the islands in the N. ½ of N. W. ¼ of sec. 33, the most easterly of these islands being the one on which the Little American mine is located. The south shore of the lake eastward from Rainy Lake City to the line between Itasca and St. Louis counties is skirted by this belt of rock, and the islands in the S. E. ¼ of sec. 27, the S. E. ¼ of sec. 26, the S. ½ of sec. 35, T. 71–22, and some small reefs near the centre of sec. 30, T. 71–21, are composed of the same. This belt of schists varies somewhat in lithology, being composed of sericitic, chloritic and hornblendic schists, which are quite fine-grained and usually quite siliceous. The smaller and more eastern of the islands in the S. E. ¼ of sec. 26 has a small amount of more acid and lighter colored rock than is usual in this belt. This rock consists of scattered quartz grains imbedded in a siliceous and schistose matrix; it perhaps represents an ancient quartz porphyry.

Further mention and description of parts of the Keewatin will be found in the section entitled "Description of veins in general and of individual properties."

The diabase dikes. These are not very numerous in the area here reported on, and the total amount of such rock is very insignificant when compared with the rocks of the three series already described. The dike rock is dark, tough and heavy; it varies much in grain in the larger dikes, according to the distance from the dike walls, the interior being coarser than the exterior. The rock is usually an ordinary diabase, with the ophitic structure, and is composed essentially of augite and plagioclase feldspar. Several dikes were seen in the syenyte a short distance below Koochiching falls, and a larger one occurs in the same rock in the N. W. ¼ of sec. 35, T. 71–24. The largest dikes seen are those near the mouth of Jackfish bay; while these two are not strictly parallel, they both have a general northwest-southeast direction. The more eastern of these cuts through rocks which belong to the three rock systems of the region. The exact age of these dikes is not known. They are, however, later than all the other rocks of the region which they cut, and they have not been subjected to the same forces which produced so pronounced cleavages in the older rocks. During the Keweenawan time there were great numbers of basic eruptions and injections in the Lake Superior basin, and the dikes of the Rainy Lake region may perhaps date from the same time.

Glacial deposits. As has already been stated, the rocks around Rainy lake are usually not covered by glacial drift or later deposits. In some places, however, there are small areas where there are thin sheets of till concealing the bed rock, and glacial boulders are common throughout the whole region. The general direction of glacial movement across the Rainy Lake basin, as shown by scratches on the rocks, was from northeast to southwest. Below are given a few heretofore unpublished courses of glacial striæ in the Rainy lake region referred to magnetic north.*

Centre of west side of S. E. ¼ sec. 19, T. 70–18, south shore of Rainy lake,	south 30–35° W.
N. E. ¼, N. W. ¼ sec. 30, T. 71–23, south shore of Rainy lake,	south 30° W.
West line of sec. 29, T. 71–23, south shore of Rainy lake,	south 40° W.
S. W. ¼, S. W. ¼ sec. 29, T71–22, south shore of Rainy lake,	south 45° W.
N. W. ¼, S. E. ¼ sec. 28, T. 71–22, east end of Grindstone island, Rainy lake,	south 33° W.
N. W. ¼, N. W. ¼ sec. 30, T. 71–21, small island at east end of Dryweed island, Rainy lake,	south 42° W.

The level area devoid of rock which begins at the west end or the outlet of Rainy lake is underlain by a considerable thickness of glacial deposits. These deposits consist of clays, which are often calcareous and sandy, and are quite frequently bluish in color. Scattered throughout these clays are small pebbles of various kinds of rocks, the most common of which is a fine grained yellowish or pinkish limestone; sometimes fragments of this limestone are found which contain a few fossil remains. These clays are thought to have been deposited from melting ice and from streams flowing into the glacial lake Agassiz. This lake covered the Red river valley, the Lake of the Woods and Rainy Lake areas, and a large amount of territory to the west and northwest at the close of the glacial period; the history and deposits of this great glacial lake have been carefully investigated by Mr. Warren Upham.† The thickness of the clay deposits along that part of the Rainy river, shown on the geological map, probably does not much exceed forty feet; in general in this area the hight of the river banks above its bed is a direct measure of the thickness of the clays.

There are no post-glacial formations in the region except the usual soil, vegetable accumulations in swamps, and a few sand beaches, mostly derived from the clays by the washing and sorting action of the lake's waves.

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*Other lists of glacial striæ in this region have been published by A. C. LAWSON (*Geol. Survey Canada*, vol. iii, pp. 164F–169F, 1889); H. V. WINCHELL (*Minn. Geol. Survey*, Seventeenth Annual Report, 1888); WARREN UPHAM (*Minn. Geol. Survey*, Twenty-second Annual Report, pp. 35–40, 1894).

†*Geol. and Nat. Hist, Survey of Minnesota*, Eleventh (1882) Annual Report, pp. 137–153, 1884. *Ibid.*, Final Report, vol. ii, pp. 517–527, 1888. *U. S. Geol. Survey*, Bulletin 39, 1887. *Geol. Survey of Canada*, Annual Report, new series, vol. iv, pp. 1E–156E, 1890. Also in a monograph of the U. S. Geol. Survey entitled "The Glacial Lake Agassiz."

Auriferous gravels forming placers are not known about Rainy lake. Some search for placers has been made, but there seems to be no probability that any will be found.

Auriferous gravels may have existed in some of the old water courses just before the Glacial period, but if they did thus exist, which is improbable, they were entirely removed by glacial agencies. Since that time there has been no erosion violent enough to produce any gravel deposits. To be sure, gravels can be found in some of the depressions, but these are of glacial origin, and consequently are not necessarily derived from the auriferous rocks near at hand, but may have been and probably were transported many miles; moreover, in the glacial gravels there has been no assorting of the various constituents and concentration of the heavier portions, and so the gold, if it does exist in the gravels, is scattered through them indiscriminately and in such minute quantities as to preclude the possibility of profitable working.

Sketch of the geological history. The oldest sedimentary rocks of which we have knowledge in the Rainy Lake region are the mica schists of the Coutchiching, but what composed the surface upon which these rocks were deposited is now unknown. An immense thickness of nearly uniform deposits was built up during Coutchiching time, and at the end of this period of deposition there was possibly a period of cessation of deposition accompanied by elevation of the land above the sea level and by erosion. But whatever the events at the close of the Coutchiching, we know that at the beginning of the Keewatin time there was a change from the deposition of uniform rather acid rocks to deposits of the most varied nature, in which basic volcanic material played an important part. The Keewatin was a period of rapid deposition and widespread volcanic activity. After the end of Keewatin deposition there was a period of elevation and intense folding, crumpling and shearing of the then existing strata, accompanied by the intrusion of enormous masses of granitic rock. The rocks were much altered or metamorphosed at this time by the dynamic forces to which they were subjected and also by the close proximity of large masses of intrusive rock; thus the strata underwent regional metamorphism, more or less pronounced throughout the district, and contact metamorphism where intruded by the granitic masses. We know that the folding and alteration took place in post-Keewatin time, and, from the relations of similar rocks to the Animikie southeast of Rainy lake, we suppose that it occurred in pre-Animikie time. This period of folding and alteration probably left the strata in approximately the same position and crystalline condition as we now find them. The accompanying cut (figure 19) will show the general relations of the rocks of the Rainy Lake region after this period and after the erosion to which they have been subjected up to the present time.*

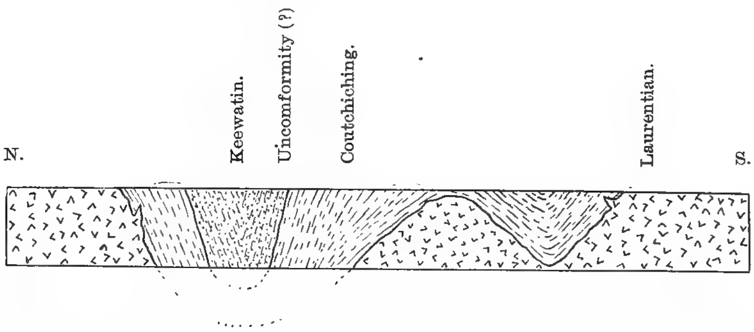


FIG. 19. GENERALIZED SECTION NORTH AND SOUTH THROUGH THE RAINY LAKE REGION.
[According to A. C. Lawson.]

Some time after the events just spoken of, possibly in Keweenawan time, the rocks of the region were cut by the diabase dikes.

From the end of the Keewatin time to the present we have no proof that the land has ever been below sea level nor that it has ever been covered by post-Archean deposits, excepting, of course, the deposits of the Glacial epoch. It is possible that the Cretaceous ocean may have extended over this region, as strata of that age are found in northern Minnesota along the Big and Little Fork rivers and on the Mesabi iron range.† If such strata ever did exist in the Rainy Lake district, all traces of them have been removed by erosion.

From Keewatin time to the present, through all the immense period during which in other places were deposited the rocks of the Taconic, Cambrian, Silurian, Devonian, and other series up to the present period, or at least during a considerable portion of this time (for strata may have been deposited here during some of these periods and afterwards removed), we must assume that this region was above the sea level and was thus subjected to erosion. After the folding the surface was probably mountainous, and the amount of rock removed must have been enormously great; the number of hundreds of feet that the surface has thus been lowered cannot be estimated. The effect of this long-continued erosion was to gradually reduce the surface of the land to a lower level, and finally, when sufficient time had elapsed, an approximately flat surface not far above sea level would result. The probability of the production of such a flat or base-leveled area in Minnesota and Manitoba

*It is quite probable that on future study, after carefully plotting the dips and strikes, the folding of this region will be found to be much more complex than this generalized cut indicates. For instance, what is represented as a single syncline in the Keewatin may really consist of several closely compressed synclines and anti-clines. But as yet data are not at hand to show the existence of these numerous smaller folds.

†H. V. WINCHELL. *Geol. and Nat. Hist. Survey of Minn.*, Seventeenth (1887) Annual Report, 1888. *Amer. Geol.*, vol. xii, pp. 220–223, Oct., 1893.

J. E. SPURR. *Geol. and Nat. Hist. Survey of Minn.*, Bulletin 10, pls. 10 and 11, 1894.

during Tertiary and early Quarternary times has been shown by Mr. Warren Upham,* and this cause will very conveniently explain the generally flat and plateau-like character of the Rainy Lake region. Since the production of this base level the hard Archean rocks have not been deeply eroded, and the surface consequently still retains approximately this base-leveled topography.

Glacial agencies have, since the base-leveling, removed any decayed rock or other material that may have remained on the rocky surface, and have produced the gently rounded and hummocky surface now existing. Since glacial time the Archean area has suffered practically no erosion, the lakes and streams following the depressions and irregularities which remained at the departure of the ice-sheet. The clayey plain to the west of Rainy lake also shows evidences of having been subjected to erosion for but a short period, and even during this time the erosion has not been extensive or violent. The surface is still monotonously flat except for the narrow, steep-sided, shallow trenches cut into it by the Rainy river and its tributaries; and only the largest of these streams have cut entirely through the blanket of clays down to the underlying rock, while none of them have excavated channels in the rock itself. This clay plain thus presents the peculiarities which are characteristic of a topographically young surface.

DESCRIPTION OF VEINS IN GENERAL AND OF INDIVIDUAL PROPERTIES IN MINNESOTA.

At the time this examination was conducted but little more than a year had elapsed since the first shot was fired in a gold quartz vein on Rainy lake. Remote from railroads, with not even a wagon road at that time to connect it with the rest of Minnesota, this region must of necessity have a slower development than other new districts of equal natural resources but greater accessibility. Reached by a hundred or more miles of canoeing, Rainy lake had, prior to 1894, been seen, aside from those who traveled the "Dawson Route" in the "seventies," only by a few trappers, pine estimators, explorers and natives. The few farmers and traders who remained on Rainy river after this route across the country from Fort William to Fort Garry was abandoned—owing to the construction of the Canadian Pacific railway—rarely left their farms or trading posts to go to Rainy lake; and the few lumbermen engaged in their work around the lake were there only when the rocks were covered with snow. So it is little to be wondered at that the quartz veins remained undiscovered and undisturbed. Gold is usually found in placers and from them traced to the lodes whose rotting has produced the placers. But here there are no placers, and the veins are not rotted to any depth—another reason why they might easily be overlooked or condemned as barren. But explorers for mineral deposits have sharp eyes. They examine everything that falls beneath their gaze. With pick and pan they pound up and wash every piece of rock that has a rusty stain, every fragment of quartz that comes into their hands. To them one species of rock is as good as another. In fact they frequently cannot tell the rocks apart or any of their names correctly. But an explorer's unaided eye can often detect at a glance a speck of gold that a mineralogist might pass over with a magnifying glass. His scent is keen and his zeal unflagging. Thus it happens that he sometimes stumbles upon discoveries in unexpected places.

The recentness of gold discoveries at Rainy lake, and its remoteness from railroads, have delayed development. It can hardly be said that there are any mines as yet in the entire district. The depth of the deepest shaft did not exceed forty-five feet at the time of examining it, and there are no underground levels. But one five-stamp mill is thus far set up in the region—that of the Little American company, and not more than 500 tons of ore have been milled. The result of operations here, however, has been sufficiently encouraging to induce several other companies to order mills, and it is expected that there will be half a dozen mills in operation before the end of 1895.

Throughout the region quartz veins are common and even abundant, but most of them are small and insignificant and contain no minerals of economic importance. These small veins, known as gash veins, cut the rocks in various directions as narrow ribbons which gradually taper to a point and disappear; they are thus of limited length and are at most only a few inches wide, the majority being less than one inch across. They are found in all the rock series of the region and are especially noticeable in some of the gneisses and granites. These small gash veins are not known to be of any value, and exploitation of them is useless.

The prospecting for gold is now being conducted in three different classes of deposits, if we include those of the Canadian side as well as those in Minnesota. These three classes are (1) Segregated veins, (2) Fissure veins, (3) Fahlbands; the first two being properly called veins, the last being rather belts of the country rock charged with an unusual amount of metalliferous material.

1. SEGREGATED VEINS.

The veins on the south side of Rainy lake, and hence all those in that portion of the gold district which lies in this state, are of the variety known as "segregated veins." They are conformable with the bedding or foliation of the schists, but their gangue, being chiefly quartz, differs entirely in mineralogical composition from the enclosing rocks. This class of veins may extend with unbroken continuity for a considerable distance through the country rock, or may form lens-shaped bodies of limited extent, occupying a more or less distinctly defined belt of country. They vary in thickness from an inch to five or more feet, and may extend continuously for fifty or a hundred feet, or may pinch out in a shorter distance. When one of these quartz lenses is found, usually others exist close by in the direction of the strike; and, moreover, two or three of these lenses may be

* *Amer. Geol.*, vol. xiv, pp. 235-246, Oct., 1894.

found side by side, or overlapping each other, being separated by only a few inches of the country rock. Thus there commonly exists a belt of rock, from one to ten or even more feet in width, in which quartz lenses are common; and in this belt the rock around the lenses is more or less completely impregnated with quartz. To this belt of quartzose rock, including the quartz lenses, the miners and explorers loosely apply the term *vein*. The "vein" may thus be several feet in width, but it is not composed wholly of vein material; in fact, it is seldom more than half quartz, and usually the quartz makes no more than one-fourth of the total. The accompanying figure represents the surface exposure of one of these veins; it also represents fully as well a vertical cross section of the vein. The areas of undulatory lines indicate the country rock, and the darker areas the quartz lenses, while the dotted area represents the belt of country rock which is more or less impregnated with quartz. The last two parts form the vein, using this term in its larger sense.

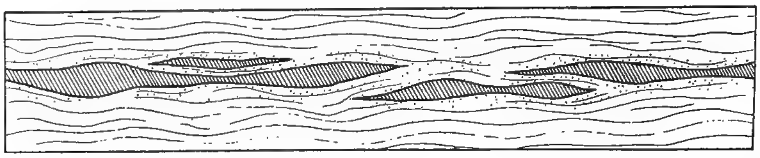


FIG. 20. GENERALIZED SURFACE SECTION OF ONE OF THE SEGREGATED VEINS.

The minerals occurring in the veins are not many. The lenses are composed of pure white, coarsely crystallized quartz; sometimes no other mineral is present. Usually, however, and always in the gold-bearing veins, there is some pyrite and a dark chloritic material which can generally be referred to fragments of the country rock. Pyrite is also frequently disseminated through the quartz-impregnated rock which surrounds the lenses. The gold occurs associated with the pyrite, but sometimes small flakes can be seen in the white quartz apparently entirely separated from the pyrite. Where the veins have weathered or decayed, particles of gold, the size of a pin's head, or occasionally much larger, can be found on the surface of the vein in cavities left by the decay of the pyrite. Most commonly no gold is visible to the unaided eye. The gold is confined principally to the quartz lenses, but also occurs in small amounts in the quartzose rock around the lenses.

These veins vary considerably in width and in the amount of quartz lenses in them. A vein that is ten feet wide and half to two-thirds quartz in one spot may vary in the distance of a few rods to half that width, and may contain not more than a fifth part quartz; or on account of the absence of the quartz lenses it may be almost unrecognizable. Further on it may widen out and contain a large number of the lenses. Variation in the amount of gold seems to be as common and as pronounced as variation in width, or number of quartz lenses.

On account of the water covered areas and those covered by swamps or soil, no vein has been traced any great distance, but in all probability they will frequently be found to extend more or less brokenly for several miles. The vein of the Little American mine appears again on the island just to the west of the one on which this mine is situated; while to the east and in the direction of the strike apparently the same vein appears at several places: On the south shore of Rainy lake in the S. W. ¼ of S. W. ¼ sec. 26, T. 71–22; in the S. E. ¼ of S. E. ¼ of the same section; and also on the island in the S. W. ¼ of S. W. ¼ sec. 25. Thus when a vein is known at one point it can confidently be searched for again in other exposures along the strike, but nothing can be safely predicted as to its size and richness at other points. These facts can be determined only by exploitation and assays, but a vein which has a considerable width and richness at one point will more probably have the same characters at other points. In making these statements concerning the extent of certain veins over considerable distances, reference is had only to the larger and more pronounced ones, *i. e.*, those which are several feet in width, and which have a number of quartz lenses lying side by side or nearly so. Single lenses of quartz are not uncommonly found, but these are of only small size, and others cannot always be found by following along the strike of the first.

As has been already stated, these veins run parallel to the strike of the cleavage of the country rock. They are thus narrow beds now standing in a nearly vertical position and extending indefinite distances. They occur in the rocks of both the Keewatin and Coutchiching. The veins found in the Coutchiching rocks are almost entirely of pure quartz, containing very little other mineral matter. They are very poor, or entirely lacking in gold. None of the veins in this series of rocks have as yet proved of value. The veins in the Keewatin rocks are richer, and are the only ones in which paying amounts of gold have been found on the Minnesota side of the lake. The best veins occur in the greenish schists of the Keewatin. As far as known the most promising belt of this rock is that which comes to the shore at the head of the bay in the N. ½ of sec. 32, T. 71–22, and extends eastward from there, including the Little American island, and those just to the west of it, a narrow strip along the south shore of the lake eastward from Rainy Lake City to the west line of St. Louis county, and the small islands just to the north of this shore. Another belt of this rock just touches the north side of Dryweed island, and in it is the Lyle mine, near the centre of the S. E. ¼ of sec. 23, T. 71–22.

A consideration of the manner in which these veins were probably formed may throw some light on their exact nature. The cleavage planes of the country rock, parallel to which lie the veins, while trending on the whole in one general direction, still vary to a certain extent in their directions in distances of a few inches or feet, *i. e.*, they are undulating. An attempt was made to indicate this fact in the cut (figure 20, above) representing a section of one of these veins; here the undulating lines represent the cleavage planes of the rock. This

cleavage is seen to be undulating or wave-like in form, in a vertical as well as in a horizontal section. The surface of one layer of the rock may be very roughly likened to the surface of a lake with a "choppy" sea; just fitting into this surface is another complementary one of the rock layer next adjacent. Along the veins there has been some slipping (or faulting) of the different layers on each other; that this is the case is indicated by the sheared and crushed condition of the rock and by the frequent slickensided surfaces. When this faulting occurred, especially where there was no great pressure normal to the fault plane, there would be formed certain irregularly lens-shaped cavities, where the surface of one layer did not fit the surface of the next adjacent one. These lens-shaped cavities are now represented by the lenses of quartz. This faulting would not be confined to slipping between two layers alone, but would occur between several adjacent layers, so that the faulted area is not strictly a plane, but a bed of several inches or feet in thickness. How great this faulting has been we do not know, but that the area of weakness, in which were crushed rock and cavities, extends to a considerable depth seems quite certain. In this area of weakness, solutions would easily travel, and mineral matter would be deposited from them; thus would occur the impregnation of the crushed rock and the filling of the cavities. Under this view of the origin and nature of these veins it is seen that they lie along lines of faulting, and that they could thus receive solutions emanating from great depths; thus these veins are in many features closely analogous to true fissure veins.

General considerations bearing upon the question of the source of the metalliferous constituents of these veins have already been given. In this connection, however, the views of Dr. A. C. Lawson upon this subject are pertinent and interesting, coming from one who has carefully studied the region under consideration. He says:*

"The distribution of veins and metalliferous deposits in the Archean has further an interesting bearing upon the question of the history of these rocks. The Laurentian rocks of the region are remarkably barren of metalliferous deposits. The upper Archean, particularly the Keewatin series which is largely composed of volcanic rocks, is rich in such deposits as native gold (with a little associated silver), iron ores, copper pyrites, iron pyrites, mispickel, galena and zinc blende. These minerals are abundant in the Keewatin series, though, of course, only occasionally found sufficiently concentrated to be of economic value.

"There can be but little doubt that their occurrence in these rocks is intimately associated with the volcanic rocks, although the period of their formation is not necessarily that of the formation of the volcanic rocks themselves. Now, unless we regard the floor upon which the upper Archean was deposited to have been the original crust of the earth, for which supposition we have no good evidence, we must assume that it was made up of ordinary strata, either volcanic or sedimentary, or composed of both. As such it is probable that it was traversed by veins; and that in the volcanic portions, if not elsewhere, these veins were metalliferous.

"But in the Laurentian we do not find anything like the number of veins that are found in the Upper Archean, and those that are occasionally observed are not metalliferous. The simplest explanation of this marked difference between the Upper and Lower Archean, as regards veins and metalliferous deposits, appears to the writer to be precisely that which gives a satisfactory account of all the other features of the region, viz.: that the Laurentian rocks have passed through a state of fusion, while the superincumbent Upper Archean remained unfused. This fusion would cause the dissemination throughout the magma of whatever metalliferous deposits had been segregated in veins, so that they could not be detected by ordinary means. The veins which cut the Upper Archean are probably, as before suggested, due to aqueous emanations from the Lower Archean magma, the metals in the veins being probably derived from the volcanic rocks traversed by these emanations, so that the very causes which obliterated veins and metalliferous deposits in the lower portion of the Archean may be said to have given rise to those in the Upper Archean."

Little American mine. This vein, the first to be discovered and developed, belongs to the class of segregated veins. Situated on a small island in the N. W. ¼ of sec. 33, T. 71–22, one hundred miles from any railroad, and developed in the face of all the obstacles to be met with in a new district, it has served to attract attention to this undeveloped portion of our state, and, whether it proves to be the most profitable mine in the region or not, it will in this way always be remembered as the most useful.

Geo. W. Davis discovered the vein while prospecting alone about the last of July, 1893. Reaching the island one evening about dark he had no opportunity to examine the quartz which he saw until the following morning when he "panned" it and obtained gold. Mr. Davis remained on the island and in the vicinity for nearly a month, and then went only as far away as Fort Frances to renew his store of provisions. On his return, about the last of August, he brought back with him a man named Quirk and a blacksmith from the "Fort," and together they fired the first blast on the 29th day of August, 1893. Subsequently going to Duluth with samples of his ore and telling of his discovery, a company called the Bevier Mining and Milling company was organized in January, 1894, with A. S. Chase, "Hutch" Bevier and "Jeff" Hildreth as incorporators. Having some trouble to secure title to the land it was purchased from the government by using the right of selection or "scrip" of the St. Paul, Minneapolis & Manitoba railway. Active operations were at once begun under the direction of Mr. Hildreth, and a five-stamp mill (see plate O, figure 1) was set up on the mainland at Rainy Lake City, about one mile from the island, where the shaft was sunk. This mill began stamping on July 16, 1894, and continued with some interruption until September 24 of the same year, when, having used all the ore in stock and finding the cost of the operation too great, it was shut down. Shortly afterwards the operation of the mine and mill passed into other hands and plans were laid for work on a more systematic basis. A casual inspection of the mine will reveal a

*Congrès géol. international, 4me Sess., 1888, p. 145.

woeful lack of business ability in the arrangement and execution of the operations of mining and milling. The expenses must have been at least double what they should have been, even with so many difficulties to overcome. The hole in the ground, called by courtesy a shaft, was about 10 x 40 x 44 feet, and was as ragged a cavern as can be found in the state. With no timbering, no pumps, nothing but a hand windlass for hoisting ore, rock and water, and the mill a mile away, it is a good example of the folly of robbing a mine in order to provide ore for present purposes without proper development for future mining. Every item of expense must necessarily have been abnormally large by such poor management as is here displayed.

As to the operation of the mill the following quotation from a letter received from Mr. A. S. Chase, one of the directors of the Bevier Mining company, contains considerable reliable information:

"From the best information I have the mill ran in all fifty-two days. The nearest estimate as to quantity of ore crushed is 500 tons. We have no record of each clean-up, but the actual shipments of bullion were: August 10, $362.30; August 20, $1,058.85; September 18, $2,481.76; October 18, $732.42; total, $4,635.33. The cost, as near as we can tell, was about $7.00 per ton for mining and milling. With proper management it can doubtless be mined and milled for $3.00 per ton. We have but five stamps, and of course the cost of milling would necessarily be large, but there are other reasons for the great cost of producing this bullion, which can be easily overcome. The mill produced all the way from eight to twenty-seven ounces of bullion per day, showing very clearly that quantities of rock were crushed which, with proper sorting, would not have been used, especially with this little mill. It is certain that there was no attempt at deception, and I am fully convinced that gold in largely paying quantities exists in the Rainy lake region."

The vein is about ten feet in width and dips south about 80°. Its strike is north 80° east, and it is believed to run across the next island west of the Little American. The ore is gray quartz with streaks and masses of the schist which constitutes the country rock enclosed in it. It contains a rather small amount of pyrites and some visible gold. Less than five per cent., and perhaps less than three per cent., of the ore goes into the concentrates, which have an assay value of about $12.50 per ton. Samples of the ore taken from the vein at the depth of ten feet, and from the top of the stock pile where the ore from the bottom of the pit was supposed to lie, assayed $11.51 ($11.39 gold and $0.12 silver) and $3.37 ($3.31 gold and $0.06 silver), respectively.

Big American mine. This is the homestead of George Davis, the discoverer of gold at Rainy lake. The property constitutes the southwest corner of Dryweed island. A pit five feet square and five feet deep has been dug in the usual siliceous sericitic schist of the island. In the pit are three quartz lenses, none of them more than a foot in width. The rock at the pit is more schistose and greener in color than the adjoining rock. The strike is north 70° east (mag.), and the dip is 90°. Exposures near by show other quartz lenses along the strike a few yards from the pit, but not enough work has been done here to show the width and probable extent of the vein.

Other prospects. In the vicinity of Rainy Lake City are several places where some work has been done, but the veins are small or the exploitation has not gone far enough to show clearly their extent and value. Some of these prospects will be mentioned below.

On the eastern end of the island in the S. W. ¼ S. W. ¼ sec. 25, T. 71–22, a shaft has been sunk. It was reported to be down to a depth of twenty-eight feet, but in October the work had been abandoned and the shaft was partially filled with water; a short drift has been run out towards the south. The vein here, *i. e.*, the belt of siliceous rock in which the quartz lenses occur, is about three feet wide as exposed at the surface.

The blunt point of land in the S. W. ¼ S. W. ¼ sec. 26, T. 71–22, is crossed by another vein, which has been uncovered at several places. In some places there is a width of nearly six feet of almost pure white quartz. This vein is probably a continuation of the one just mentioned on the island.

In the S. E. ¼ S. E. ¼ sec. 23, T. 71–22, is a small island on which is what is known as the "Old Soldier Mine." The island is made of mica schist in which are small veins of quartz and some beds or dikes of gneiss or foliated granite. This granitic rock varies in color, being light or dark according to the amount of biotite or hornblende it contains. A considerable amount of pyrite is disseminated through this rock.

The large island in the N. W. ¼ of sec. 26, T. 71–23, known as Kingston island, has a few small veins running across it. Some work is now being done upon these, but at the time of our visit it had not progressed far.

The vein of the Little American mine is seen again on the island nearest west of the Little American island, and the company have commenced operations here and are uncovering the vein and have started a drift alongside of it.

It was formerly supposed that segregated veins are not so persistent as fissure veins, and that they are not so likely to be productive in depth. This view does not appear to have a basis in fact, however, since "recent mining operations have materially modified the received views respecting the value and persistency of the so-called segregated veins. Many of them are of great thickness and extent, and, after having been worked to very considerable depths, have been there found as productive as they were nearer the surface. The character of the veinstone of such deposits frequently appears to in no way vary from that of true fissure veins, from which they often differ in no respect except that their course is often parallel to that of the strata between which they lie." (Phillips, Ore Deposits, p. 91).

II. FISSURE VEINS.

True or fissure veins have already been briefly described, and the prevalent theory of their origin outlined. Their distinguishing feature is their entire independence of the strike or foliation of the enclosing rocks. Indeed, because of the wavy line of strike of the crystalline and semi-crystalline rocks, a fissure vein almost always cuts across the strike in some portion of its course. The walls of fissure veins have usually a more direct and even course than those of other veins, and are smoothed or "slickensided" in a similar manner.

The veins in the vicinity of Rainy lake which present the characteristics of fissure veins are those in the vicinity of Shoal and Bad Vermilion lakes, east of Seine bay, at the east end of Rainy lake. Occurring for the most part in a granitic rock, they strike north and south or northwest and southeast,—almost at right angles with the series of segregated veins. The quartz is somewhat different in appearance, perhaps due largely to the fact that it is richly charged with the sulphides of iron, copper, lead, zinc and silver, and near the surface with the oxydized alteration products of these minerals. The fissure veins exploited when this examination was made are in Canadian territory.

III. FAHLBANDS.

Fahlbands are belts of rock, often of considerable width and extent, impregnated with sulphides of iron, copper and zinc, and sometimes, also, of lead, cobalt and silver. There are usually several of these belts having a considerable degree of parallelism with one another, and sometimes traceable upon their line of strike for several miles. The amount of ore contained in such belts may be quite considerable, but it is only in a few localities found to be sufficiently concentrated to render its exploitation profitable. Fahlbands are usually found in regions of gneiss, mica and hornblende schists, talc schist, or chlorite schist. Veins of quartz may be present in these fahlbands, running parallel with or intersecting them at various angles, but they are sometimes wanting entirely. There is usually a gradual transition from the metalliferous rock of the fahlband into the barren rock on either side, with which the fahlbands are usually conformable. When intersected by dikes of eruptive rock or veins of quartz, there is frequently a considerable degree of enrichment at the planes of intersection. There are several points around Rainy lake where prospecting is in operation in fahlbands. Some of these are not worthy of mention. The best example of this class of deposit is the Lyle mine.

Lyle mine. This is situated on a narrow point which runs out from the north side of Dryweed island near the centre of the S. E. ¼ of sec. 23, T. 71-22, two and one-half miles northeast of Rainy Lake City. This property was located in the winter of 1893-94 by William and Edwin Ward, of Duluth. Work was begun on the shaft, which is eight feet square, on September 8, 1894, and, at the time of our visit, a month later, it had reached a depth of twenty-two feet. The shaft is down in a peculiar kind of siliceous rock which consists of narrow bands of (1) Finely divided quartz, (2) A dark greenish material, perhaps largely chlorite, and (3) Bands of 1 and 2 combined. This rock constitutes a band about twelve feet wide. Throughout it are numerous quartz stringers or lenses of all sizes from those a fraction of an inch in thickness to one which, where exposed, is two and a half feet across. The quartz lenses and the belt of rock in which they occur contain a considerable amount of pyrite, more than is common in the veins about Rainy Lake City. Masses of coarsely crystallized siderite are found in some of the quartz lenses. This belt of siliceous rock, including the lenses, is probably two-thirds or more quartz, and it will be necessary to mine and stamp the whole rock as ore, as it is impracticable to separate the quartz lenses. Moreover, the siliceous rock, as stated above, contains considerable pyrite, and possibly some gold.

The country rock at this place is composed of chloritic and sericitic schists and a green schist in which are many small spots of siderite. The strike is N. 75° E. (mag.) and the dip 75° to 80° north of this line. Just to the south of the little point on which the shaft is situated, on the main land of Dryweed island, the rock is the usual sericitic schist which has been mentioned before (page 201) as forming Grindstone and Dryweed islands. Here a few quartz lenses occur, but they have not yet been uncovered so as to show their true size and extent.

The surface of the vein at the shaft is rusted and more or less decayed, but this condition does not extend downward more than four to six inches, except along cracks.

TREATMENT OF RAINY LAKE ORES.

The development of the Rainy Lake region has not been sufficient to furnish data on which to base a statement as to the best method of treatment for its ores. Conservative and business-like methods and principles would lead investors to be absolutely certain that ore existed in quantity sufficient to supply a stamp mill for a few years, and that it was of such a character as to be best treated in a particular kind of stamp mill, before risking their money in the purchase of one. And in order to gain such information it would be necessary to sink shafts numerous enough and deep enough to prove the quantity and quality of the ore. The mere fact that four or five stamp mills have been built for use in this region, where there is not as yet a shaft or a drill hole seventy-five feet deep, is in itself sufficient proof that the mines are being developed by parties of little or no experience in the mining business. There can be only one result of such hasty, ill-advised methods of procedure. Some, if not all, of the companies, will soon find themselves financially embarrassed. The money which should have been spent in mine development will have been spent for machinery. When the stamp mills are on the ground and ready for operation there will be no ore to run them for any length of time, and not enough development in the mines to enable them to produce what the mills require. Thus the mills must be shut down, and the public will say it was because there was no gold in the ore. The stockholders will be discouraged, and the treasury of the company will be depleted without means of replenishing it. In other cases the free milling ore will so rapidly pass into refractory ore, as the depth of the mine increases, that the mill which was built to treat the surface oxidized ores is unable to extract the gold from these more refractory ores, and must be discarded—a dead loss to the company—and a new plant purchased. All of these things will exert a damaging influence on the reputation of the district as a whole, and should be avoided if possible. In a new district double precautions should be taken to insure against mistakes. Two or three shafts each 100 feet deep should be sunk and connected with levels on every property before a stamp mill or other plant is purchased. Then,

with the mine opened up, and enough ore in stock to run the mill for six months, the mine will have a bona fide value. No difficulty will be experienced in raising money to buy the machinery needed. No hesitation will be felt as to what process to use. No trouble will be had in keeping the mill supplied with ore. The experience of the Lake of the Woods district should not be repeated at Rainy lake, but that is just what will happen if matters proceed as they are begun. Too great stress cannot be laid on this point. The old adage that "haste makes waste" is nowhere better exemplified than in matters of this sort. For the good of the pioneers, who deserve to succeed because of their confidence in the new region, and their efforts to develop it, no less than for the good of the district, we would urge upon the owners of prospects to "go slow" and develop their properties before ordering expensive concentrating and metallurgical plants.

As already stated, the ore which occurs within fifty feet of the surface of the ground at Rainy lake is free-milling, and the proportion of concentrates will not exceed ten per cent. How much this percentage will be increased in depth is uncertain, but that there will be an increase is to be expected. With five or ten per cent. of the ore going into the concentrates there will be required facilities for treating these refractory sulphides on the spot. The expense of transportation to a smelter and the high smelter charges make shipping out of the question. Some method of treating the sulphurets cheaply at the mine or on the lake must be introduced.

In this connection the description of barrel-chlorination by the Thies process as conducted at the Haile mine, Lancaster county, South Carolina, is of interest.* Working on a large scale, ore which assays $4.50 per ton on an average and contains ten per cent. of concentrates is treated at a profit by this process. The value of the roasted concentrates amounts to $30.00 per ton, and the cost of roasting and chlorination is said to be $4.62 for one and one-third tons raw pyrites. After thoroughly roasting the sulphurets the roasted material is placed in lead-lined iron cylinders 60 x 42 inches, which rotate on their major axes twenty times per minute. Chlorine gas generated in these barrels dissolves the gold in from four to eight hours, and it is then precipitated by ferrous sulphate. With an abundance of cheap fuel and water-power this process might be practicably introduced in the Rainy Lake region, and operated in conjunction with stamp mills and amalgamation.

OTHER RESOURCES.

This report is devoted primarily to a discussion of the gold-bearing rocks of the Rainy Lake region, but it will not be out of place to call attention to other natural resources, as these must play an important part in the development of any mining district. Moreover, the presence in the vicinity of Rainy lake of an abundance of natural resources, other than the gold, is destined to aid very materially in the rapidity of settlement and development of the northern parts of Itasca and St. Louis counties.

Useful mineral substances. In the large pegmatyte veins or dikes, which occur especially in the mica schists along the south shore of the eastern arm of Rainy lake and on the shores of Kabetogama lake, are plates of mica (muscovite) two or three inches in diameter. As yet no mica has been found in sufficient quantity or in large enough plates to be economically useful, but more careful exploration of these pegmatyte veins may be rewarded by the discovery of larger masses of this mineral.

Other minerals, such as iron pyrites, sphalerite (zinc blende) galena and copper pyrites, occur in the Rainy Lake region, especially in the quartz veins, but it is hardly probable that large amounts of any of these will be found.

The Keewatin rocks of this district are of the same geological age and of the same general character as the rocks in which are the rich iron deposits of the Vermilion range and some parts of the south shore of lake Superior. Deposits of iron ore have already been reported from the Seine River country, but as yet no careful exploration for iron ore has been attempted. We wish to call special attention to the probability of the existence of large masses of iron ore in the Rainy Lake region, and we feel that exploration in this line is more likely to result in the discovery of mineral wealth than exploration for any other mineral except gold. The rocks marked Keewatin on the map (plate N) are the ones in which exploration for iron ore should be carried on.

Many of the granites and syenytes, and some of the other rocks, will make excellent building stones. Good material for grindstones, whetstones and hones, and probably also for roofing slates, exist in the Keewatin rocks. The numerous limestone fragments found in the clays along the banks of the Rainy river have sometimes been burned for lime by the settlers. The clays to the west of Rainy lake contain beds which will evidently make good bricks, and some of the beds will probably be found to possess the characteristics necessary for some kinds of pottery.

Coal has been reported a number of times from the banks of the Big Fork and Little Fork rivers, which are in Itasca county and southwest of Rainy lake. This coal occurs in the form of lignite in the Cretaceous shales, which are known to outcrop in places along these rivers, and it is probable that rocks of this age exist, although usually buried under a considerable thickness of glacial drift, in most of Itasca county and the counties to the west. On account of the discovery and recent development of lignite beds in the vicinity of Redwood Falls, it is thought best to call attention to the possibility of the existence of similar beds in the region to the southwest of Rainy lake. This lignite in Minnesota does not seem destined to be of any great value, but possibly some of it may prove of local importance. In this connection we quote the statements made in reference to coal in Minnesota by the senior author of this report some two years since:

"The opinion of the state geologist and the writer has been frequently expressed that the only coal of any sort in the northern part of the state is in thin seams of brown coal, occurring in Cretaceous shales, which

Trans. Am. Inst. Min. Eng., vol. xix, p. 607.

were found in patches on the Little Fork river by the writer in 1887. This coal is not of good quality, and the discovery of large amounts in thick beds would not be of such great importance as the newspapers would have us believe.

"At the same time, lignite is used to a considerable extent in treeless regions as fuel for ordinary heating and cooking purposes. In Texas and Dakota such coal is mined in considerable quantities. Grates of a peculiar pattern are devised in which to burn this coal, and it plays quite an important part in the domestic economy of those regions. It is used in the form of briquettes in Germany. These briquettes are made by drying the brown coal until the water it contains is nearly all driven off, and then subjecting the mass to a pressure of 1,500 to 2,000 atmospheres. The resulting briquette is elliptical in form, about six inches long and one inch thick. It is so hard that it will not absorb water, even though laid in water for some time. The coal is too fine-grained and not compact enough to use in blast furnace practice. If this brown coal should be found dehydrated and consolidated by heat or pressure consequent on eruptions or excessive faulting in the rocks, it would have a much greater value. It is not impossible that such deposits may be found in some of the large areas northwest of Duluth, as yet but little explored by the geological survey. It is quite desirable that some further examination be made of this region in connection with more thorough and careful mapping of the rocks of the Mesabi range."*

Timber. The usual white and Norway pines are found throughout this entire region, but not always of sufficient size to pay for cutting. Yet, there are many places along the shores of Rainy lake and the adjoining bodies of water where there are groves of good sized pines; and many scattered areas of timber exist in the vicinity of the Big Fork and Little Fork rivers. Some of the pine has already been cut and taken to Rat Portage, but much remains to be cut as soon as the demand for lumber in this district increases. A saw mill was in operation near Rainy Lake City during the last summer, and two or three others on Rainy river.

In hardwood timber the white birch, which occurs throughout the region, and which often reaches a size suitable for lumber, may be mentioned; oak and elm of good size occur in the flat clayey district just to the west of Rainy lake.

The numerous swampy tracts of this part of the state are often covered by a dense growth of excellent spruce timber. This is used in large amounts in the manufacture of pulp and paper, and, as the more southern regions are being rapidly devastated of their timber, the spruce of northern Minnesota will soon become exceedingly valuable; growing, as it does, in the lower and damper grounds, it is not so subject to destruction by forest fires as the pine.

Agriculture. The plain of clays which extends westward and southward from Rainy lake is destined to support a large farming population. As already mentioned, these clays were deposited in the glacial lake Agassiz, and are thus of similar origin to the subsoil of large parts of the Red River valley. Above this subsoil is a considerable thickness of black loam. This land naturally supports a luxuriant growth of vegetation, and, where it has been cleared and cultivated, as in many places along the Canadian shore of the Rainy river, it has been found to yield large crops. Most all of the usual produce, excepting yellow dent corn, have been successfully grown in this district; and especially large returns have been made in oats, wheat, potatoes, cabbage, turnips and hay. There are large tracts of land south of the Rainy river, which are as yet unsettled and which are unexcelled for agricultural purposes by other land in the state. As is usual in a new mining country, the farming interests are neglected at first, but in the Rainy Lake district there is no reason why this should continue so, as the conditions for making farming a profitable business are here so favorable.

The following quotation from Dr. A. C. Lawson's report on the geology of the Rainy Lake region† is strong testimony as to the adaptability of the soil and climate of the region for the support of a dense population:

"Agriculture is perhaps the most promising of the economic prospects of the region. Rainy river, from its source at Coutchiching to Hungry Hall, flows for eighty miles through a rich alluvial plain, which, so far as can be judged from the banks of the river, is eminently adapted to support a large agricultural population. Travelers and explorers vie with one another in praising the beauties of the river and its capabilities for settlement. Mr. S. J. Dawson in his 'Report on the exploration of the country between lake Superior and the Red river settlement' says of it: 'The distance from Rainy lake to the Lake of the Woods, following the windings of the stream, is about eighty miles, and throughout the whole of this extent the land fronting on the river is fit for settlement without, I may say, a single break; indeed, I have never seen anything to equal it in my experience, except at Swan river and on the Assiniboine.' * * * Prof. H. Y. Hind in his account of the country examined by the same expedition says: 'No part of the country through which we have passed from lake Superior northwards can bear comparison with the rich banks of the Rainy river thus far. The river has preserved a very uniform breadth, varying only from about 200 to 300 yards. The soil is a sandy loam at the surface, much mixed with vegetable matter. Occasionally, where the bank has recently fallen away, the clay is seen stratified in layers of about two inches in thickness, following in all respects the contour of what seems to be unstratified drift clay below. Basswood is not uncommon, and sturdy oaks, whose trunks are from eighteen inches to two feet in diameter, are seen in open groves, with luxuriant grasses and climbing plants growing beneath them.'

"A more recent authority is Mr. J. O. Bolger, P. L. S., who explored the region in the summer of 1886 for the department of crown lands of Ontario, with the special object of ascertaining its fitness for settlement. His description and opinions are more valuable than the preceding and are even more optimistic. He says:

* *Geol. and Nat. Hist. Survey of Minn.*, Twentieth Ann. Rept., pp. 179, 180, 1893.

† *Geol. Nat. Hist. Survey Canada*, part F, 1887, p. 186 F.

'I first encountered good land at the point where the forty-ninth parallel or the first base strikes Lake of the Woods, and following up Little Grassy river, which empties into the lake a couple of miles south of this point, I found, from traveling in every direction, that the block of four townships composed of Ts. 1 and 2 S., Rs. 23 and 24 E., contains a large percentage of the finest land I have ever seen, and the same description applies to the block of land lying westward between these townships and the Lake of the Woods. Little Grassy river is navigable for canoes for a distance of about eight miles from its mouth, and the land on the shore is all good, being composed of a rich calcareous drift formation equal to any soil in the best agricultural districts of Ontario.

"'The timber along the river is chiefly large, thrifty poplar, mixed with some scattering oak and swamp elm, and some evergreens, such as balsam and spruce; inland the timber changes in character somewhat from that along the river shore, as large balm of Gilead, spruce, balsam, and tamarack are met with more frequently, and the nice open bush which prevails along the river banks is changed for a tangled, brushy undergrowth; but the character of the soil remains the same. Tamarack and spruce swamps occur frequently in this section of the country, as is the case all through this large level area of good land which lies along the banks of Rainy river. These swamps were all perfectly dry this summer, and are all capable of being made into excellent land by drainage, as they lie nearly as high as the surrounding dry lands, and only require proper ditching to take the surface water off in wet seasons. The extreme levelness of the country causes the presence of so mnch swamp land here, as the surface water has no means of escaping from the low-lying portions, and, consequently, the growth of moss and swamp timber is engendered. I noticed that in most cases the beds of the little streams are deep enough to form outlets for ditches and drains, and these creek beds are usually so numerous that to drain any swamp no very long ditches would be required. In nearly all the swamps through which I passed I observed the soil to be a black vegetable mould, varying in depth from one to three feet, and always underlain by the same calcareous clay alluded to. I seldom met the muskeg proper, that is to say, the wet, shaky bog in which water is present at all seasons of the year, and which grows nothing but dwarf spruce and moss. I then paddled up Rainy river, and on both shores I found the same kind of country as I have described as being in the vicinity of Grassy river, and, as there are a good number of settlers along the river on the Canadian side, I had an opportunity to observe the soil while under cultivation, and to see the kind of crops it is capable of raising.

"'The soil I found to be most excellent in character,—calcareous clay overlain by a thin streak of whitish fine earth about six inches in thickness, and this again covered with a coating of vegetable mould; and these three mixed up together in the working of the land form a soil which cannot be excelled in any part of the Dominion. I saw along the river crops of potatoes, turnips, hay, oats, wheat, corn, tomatoes and cabbage, all grown to perfection this season, which shows that the climate, as well as the soil, is suitable to successful farming, especially when tomatoes ripen, as they certainly did this year, as well as I ever saw them ripen in the vicinity of lake Ontario. * * *

"'The timber is chiefly poplar, which grows to a great size; I have seen trees over eighteen inches across the stump, and sixty feet long clear of the limbs. Balm of Gilead, too, prevails in some sections, while spruce, tamarack and balsam of thrifty growth are everywhere met with. In some places magnificent cedar abounds, large enough for telegraph poles, shingle bolts or any other use to which cedar is applied; there are some groves of pine through this section, but it cannot be called a pine country, that is on this drift formation.'

"Such testimony as to the character and value of the land through which Rainy river flows, leaves little for me to say beyond expressing my entire concurrence in the opinions quoted as to the great suitability of the country for settlement and agriculture. Settlers are going in gradually and there are some excellent farms along the river front. * * * The river affords an easy means of access, and the levelness of the country renders roads easy to build."

This agricultural district is not confined to a narrow belt of land along the river, but has, in Minnesota, an approximate area of 5,000 square miles, between Rainy lake and the Red River of the North, and south of Rainy river. Over this area the annual rainfall varies from thirty-three inches at Rainy lake to seventeen inches at St. Vincent. The absence of hills, rock outcrops, and even of boulders, is remarkable, and the land is nearly all timbered. In short, all the qualifications necessary for a habitable region are found in this hitherto overlooked portion of our great state. It will not be surprising to see in the Rainy River valley as dense a population as is supported by any equal area in Minnesota.

Miscellaneous resources. As has already been stated in the description of the physical features of the district, there are waterfalls at the outlets of many of the lakes. Some of these streams are of considerable size, and their accessible power would be eagerly sought after if located in the well settled eastern states. By far the largest water power in the district is that of the Koochiching falls (plate O, figure 2). Here the Rainy river descends from twenty-one to twenty-four and a half feet, the amount of fall varying with the stage of the water. It has been estimated that there are 12,000 cubic feet of water flowing over this fall every second, and the power here generated averages 30,000 horse power, with a probable minimum of 20,000 horse power. This is thus seen to be by far the largest water power in the state, much exceeding that at the falls St. Anthony. A dam of from five to ten feet at the head of these falls would increase the hight of the falls as many feet, and would also raise the level of Rainy lake from two to seven feet, thus furnishing an immense mill-pond with an enormous supply of water for use in times of low water in the river. The value of this water power as an aid in the development of this part of the state cannot be overestimated.

Considerable trapping is done in the winter in this section of the country, and the trade in furs has been an important business ever since the establishment of the Hudson Bay company, which still has a store at Fort

Frances. Many of the inland lakes abound in white fish and lake trout, and the catching and shipping of these will furnish livelihood for a considerable population as soon as there are better facilities for transporting the fish to market.

Summary. It is only necessary here to emphasize the fact that in the Rainy Lake district there are many natural resources, aside from the gold-bearing veins, which have not yet been developed, and which would make the district an important one, even if it contained no gold. We wish especially to call attention to four of these natural resources, which seem destined to make this district develop with rapidity: (1) The excellent farming lands; (2) The large bodies of standing timber, suitable for manufacture into lumber and paper; (3) The large water-power; and (4) The possibility of the existence of valuable deposits of iron ore.

CONCLUSION.

Concisely stated, the facts described in the foregoing pages lead to the following conclusions: There is gold in quartz veins in the vicinity of Rainy lake. As yet the development is insufficient to warrant the positive assertion that profitable gold mining operations can be conducted there; but in certain localities the prospects are full of encouragement and promise to the conservative operator.

The best portion of the district for gold, so far as at present developed, and as indicated by the appearance and nature of the veins, and the geological conditions surrounding them, is not within the limits of our state. Some gold is found south of the boundary line, and its discovery was the starting point for the explorations so vigorously prosecuted during the past year.

If the development of operations now in progress shall demonstrate the existence of extensive deposits, as we believe will be the case, the future of the district for gold mining is assured. It is even now accessible at moderate cost; fuel, water and water-power are abundant, and labor cheap. Modern methods have made the cost of exploitation, even of refractory ores, much less than it was only a few years ago. With the large bodies of low grade ore which are destined to furnish the greater part of the world's output of precious metals in the future, the costs of mines and mills as advantageously situated with reference to wood and water as those at Rainy lake have been estimated at $2.00 a ton for mining and $3.00 a ton for barrel chlorination or for treatment by the cyanide process of ores adapted to it, and from which ninety per cent. of the metal can be saved. Where practically all the gold can be extracted by amalgamation, as at present at Rainy lake, there should be a good profit on $5.00 ore in permanent veins which have an average width of five feet or more.

The surprising adaptability of the soil and climate of the Rainy River valley for agriculture, together with its stores of timber for lumber and paper manufacture and its large water-power, instill in us the conviction that northern Minnesota is an empire by itself, destined in the near future to become the home of a large and prosperous community engaged in the occupations of farming and manufacturing.

CHAPTER IX.

THE GEOLOGY OF THE SOUTHERN PORTION OF ST. LOUIS COUNTY.

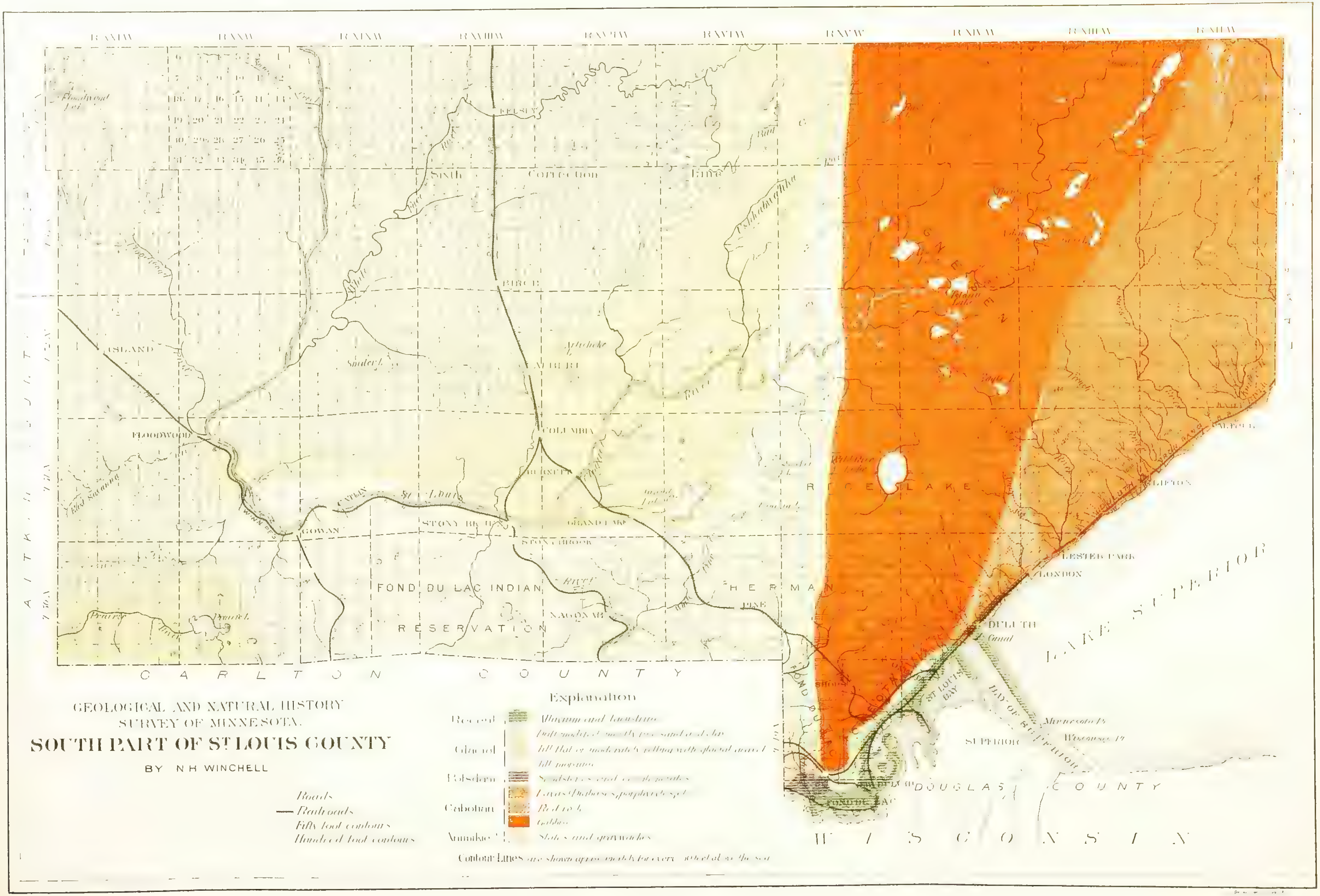
(PLATE 66.)*

BY N. H. WINCHELL.

General description. This plate includes an area that is very heavily covered with drift, and which is very monotonous and nearly flat throughout the western and northwestern two-thirds. In the vicinity of lake Superior and the lower reaches of the St. Louis river, however, the country is much more interesting and descends rapidly to the level of the lake over the brow of the gabbro hills. The descent of the St. Louis river from the upland to the lake level is over the Thomson slates (plate A), and is mostly within the limits of Carlton county (plate 56); and the special geology of the region of Duluth, extending eastward to near New London, will be found in the chapter descriptive of plate 88. The same general topographic characters extend beyond New London, except that the elevation is less abrupt, which is doubtless due to the fact that the trend of the main gabbro mass recedes from the lake further toward the east. Between the strike of the gabbro hills, which rise 600 to 700 feet above the lake, and the lake shore, the surface is broken, not only by reason of the nature of the upper surface of the Cabotian flows, but because of the roughness of the drift. This roughness is in part due to the morainic nature of the deposit, and in part to the erosion that the streams have effected since the drift was deposited. Near the lake these streams run frequently on the rock.

Geological formations. The Thomson slates are scantily exposed in the area of this plate. Yet they have their most eastern and most northern known outcrops within this area, viz.: in the valley of Mission creek, near the section line between secs. 30 and 31, T. 49–15, and nearly on the town line next south. The most northern outcrop is N. W. ¼ S. W. ¼ sec. 27, T. 51–19, near the St. Louis river. Whether these outcrops are of some portions of the Animikie or of the upper Keewatin is considered in the chapter on the Carlton plate (No. 87), to which the reader is referred.

*In the description of this plate, besides the field observations of the writer, are included those of Messrs. A. D. Meeds and J. E. Spurr. The contours about Duluth are reproduced from the Duluth sheet of the U. S. Geol. Survey.



GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.
SOUTH PART OF ST LOUIS COUNTY
BY N H WINCHELL
Explanation
Recent
Alluvium and lacustrine
Glacial
Till moraines
Potsdam
Sandstones and conglomerates
Cabotian
Red rock
Gabbro
Animikie
Slates and graywackes
Roads
Railroads
Fifty foot contours
Hundred foot contours
Contour Lines
CARLTON COUNTY
DOUGLAS COUNTY
WISCONSIN
LAKE SUPERIOR
AITKIN COUNTY
FOND DU LAC INDIAN RESERVATION
HERMAN
RICE LAKE
GNESEN
ISLAND
FLOODWOOD
GOWAN
STONY BROOK
COLUMBIA
GRAND LAKE
ALBERT
BIRCH
Sixth Correction Line
KELSEY
PINE
DULUTH
LONDON
LESTER PARK
SUPERIOR
ST LOUIS BAY

The samples collected at these places are numbered 446, 447, and 200S, 201S, and 202S, the last three having been collected by Mr. Spurr. Similar slates are exposed near the mouth of Stony brook, and at points near the railroad further southeast, and particularly opposite the mouth of Pine creek, where some vertical slates are slightly cut by the grade, but are also overlain by some fine clay of various colors—red, light-green, and yellow. Near the mouth of Stony brook, and especially at an island about a mile above its mouth (sec. 18, T. 51–18) these slates are visible. Probably they will be discovered at other places in the same region as the country becomes occupied by settlers. There are no features connected with the exposures mentioned, which need special description. As a whole these slates at this point present the facies of the upper Keewatin more evidently than of the Animikie.

The gabbro and the Beaver Bay diabase. This rock, its origin and age are discussed briefly in connection with the Duluth plate (No. 88), and more fully in the chapter devoted to the structural geology. The width of the gabbro belt transverse to its elongation is not over seven miles, at the southern termination, but where it leaves the area of this plate, north-northeastwardly, its width is about sixteen miles, and it widens still further in its course through the northern part of St. Louis county. It is mostly hid by drift, but its limits are approximately determinable by the distribution of its boulders, or by the appearance of boulders that pertain to the adjacent formations. For instance, having ascertained the general structure of the region, and knowing the direction of movement of the glacial abrasion, it is plain that gabbro boulders would not be distributed to the north and west of its line of northern and westward limits. To this statement an exception should be made for the southern portion of this area, since a westward movement of the later glaciers carried gabbro boulders as far west as the western side of this area, at least as far as Catlin, on the Duluth and Winnipeg railroad. For the same reason, although gabbro boulders may be found to the south of the commencement of the Cabotian flows, the debris of the Cabotian flows will not be found in abundance to the north of their most northern extension. This is of course subject to the same exception as mentioned for the gabbro boulders.

As to the nature of the gabbro, it will be found described in more detail in that part of vol. v devoted to the "Petrographic Geology" of the crystalline rocks, under the rock numbers collected in the area represented by this plate, mentioned at the end of this chapter. There is one feature, however, to which special attention may be called at this place. In Herman, which is northwestward from Duluth, in sections 22, 25, and 27, this rock consists, in some places, essentially of labradorite and olivine, and varies also to a strongly magnetited rock, disturbing the magnetic needle. In the first instance it may have the name of forellenstein (Nos. 513, 514),

and in the latter it is almost an iron ore (512). These variations are characteristic, according to professor Bayley, of the borders of the gabbro mass, whether on the northern or on the southern boundary.* It also presents here the microscopic peculiarity that the olivine, when present, is sometimes of later date than the plagioclase. A rare manner of disintegration of the gabbro is shown by figure 1, plate P.

Within the limits of Duluth city the gabbro is intimately associated with the so-called "red rock," and this can be traced northeastwardly, with more or less distinctness, to the northern limit of this plate. It is evinced by fragments in the drift, and occasionally by the red rock *in situ*, but it cannot be mapped independently of the gabbro itself. This is the case in Ts. 53–12 and 54–12, where it is, apparently, mingled with the basic flows, and is grouped with them. In no place, within the area of this plate, outside of the immediate vicinity of Duluth, is this rock found as a massive rock cutting the gabbro, and it is here mapped with the gabbro. The red rocks seen at the lake shore at New London and eastward are a part of the surface flows of the red rock series. The extension of Piedmont avenue, known formerly as the "Weller road," passes, at about a mile and a half from lake Superior, or two miles from the business part of the city, over some gabbro hills in which this rock is seen. It is like a scattered blotch, on the side of the gabbro, and in thin veins in the gabbro, which is also affected by the contact (Nos. 1540, 1541, 1542). The gabbro here seen is rather fine-grained, scatteringly porphyritic and sometimes marked by coarse irregularities of structure, and containing areas and nodules of silica of secondary origin, somewhat in the manner of a coarse amygdaloid. These features are also indicative of contacting on the clastics, and of nearness to the natural surface.†

The gabbro outcrops frequently on the Cloquet river. Its most northerly exposure, within this area, is in sec. 15, T. 54–13, where a ridge running northeast rises on the south side of the river, causing rapids for about half a mile. Its hight is forty-two feet above the lower end of the rapids (specimens 19M and 20M). This rock is not very coarse-grained, weathering gray, and in some places it is quite dark with the prevalence of the pyroxene elements and of biotite. These sometimes give a sort of lamination to the rock, and it breaks along these planes. Olivine is also common.

On sec. 31, T. 54–13, and extending into sec. 5, T. 53–13, is an area of exposed gabbro, causing rapids in the river, and rising fifteen or twenty feet above the general surface. This is somewhat magnetic, but no large areas of iron ore were seen. It varies from fine to coarse-grained. Near the river is a series of low, narrow ridges composed of boulders, principally of gabbro. They extend northeast and southwest, rising out of the swamp.

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*BAYLEY, W. S. The peripheral phases of the great gabbro mass of northeastern Minnesota. *Jour. of Geol.*, ii, p. 814.

†Compare the description of the gabbro at Short Line Park, plate 88, chapter xxxi.

On sec. 18, T. 53–13, gabbro occurs again (No. 43M), causing a waterfall of twelve feet, but the actual outcrop is small. A hill on the west side of the river is presumably composed of the same rock.

A large boulder of nearly white feldspar rock, or anorthosyte, occurs at the dam S. E. ¼, S. E. ¼ sec. 19, T. 53–13. This weathers white, but has small areas of darker rock resembling dark gabbro (Nos. 44M and 44aM). It has been broken up and used for filling the piers at the dam. At the dam the river descends about five feet. This dam is at the outlet of Alden lake.

Gabbro appears frequently, and sometimes in large amounts, along the river in secs. 36, 35 and 34, T. 53–14, causing falls and rapids (Nos. 45 and 46). The petrographic characters of this area of gabbro are given in the chapters devoted to that subject. It is sometimes very coarse, and contains olivine in conspicuous amounts. Between these exposures on the Cloquet and those at Duluth nothing is known of this gabbro beyond the mention already made of the outcrops in Herman.

The Cabotian surface lavas. The entire lake shore from Duluth to the eastern limits of this plate is occupied by a variety of eruptive sheets of lava overlapping each other in great irregularity, and varying from basic to acid. These extend inland as far as to the gabbro range, but they cannot be much seen owing to the drift, which is abundant. They are exposed along several of the small streams, and form various waterfalls and rapids. They can be seen in Ts. 53 and 54–12 W., and their debris constitutes there a noticeable element in the coarser drift, conspicuous along the streams. They outcrop S. E. ¼ sec. 35, T. 54–12, and extend thence northeastwardly underlying the elevated tract in section 25 of the same town, and extending into the next range east. There is, however, no favorable opportunity, away from the immediate vicinity of the lake, for studying them.

Along the lake shore they have been noted more carefully, and numerous samples have been collected and examined in thin section. These surface flows, when basic, are supposed to have been derived from the gabbro as a primal source, and from the fused clastics of the Animikie and earlier rocks when acid (36M and 37M). They probably lie upon the Animikie, or on the "red rock" which resulted from its fusion and normally separates the Animikie from the main gabbro intrusion. They issued from volcanic vents and fissures which existed along the strike of the gabbro mass, but which have now been lost by abrasion, and can never be located with precision. Owing to the prevalence of morainic drift in the area of these flows no attempt is made on the plate to separately represent the most of the red rock.

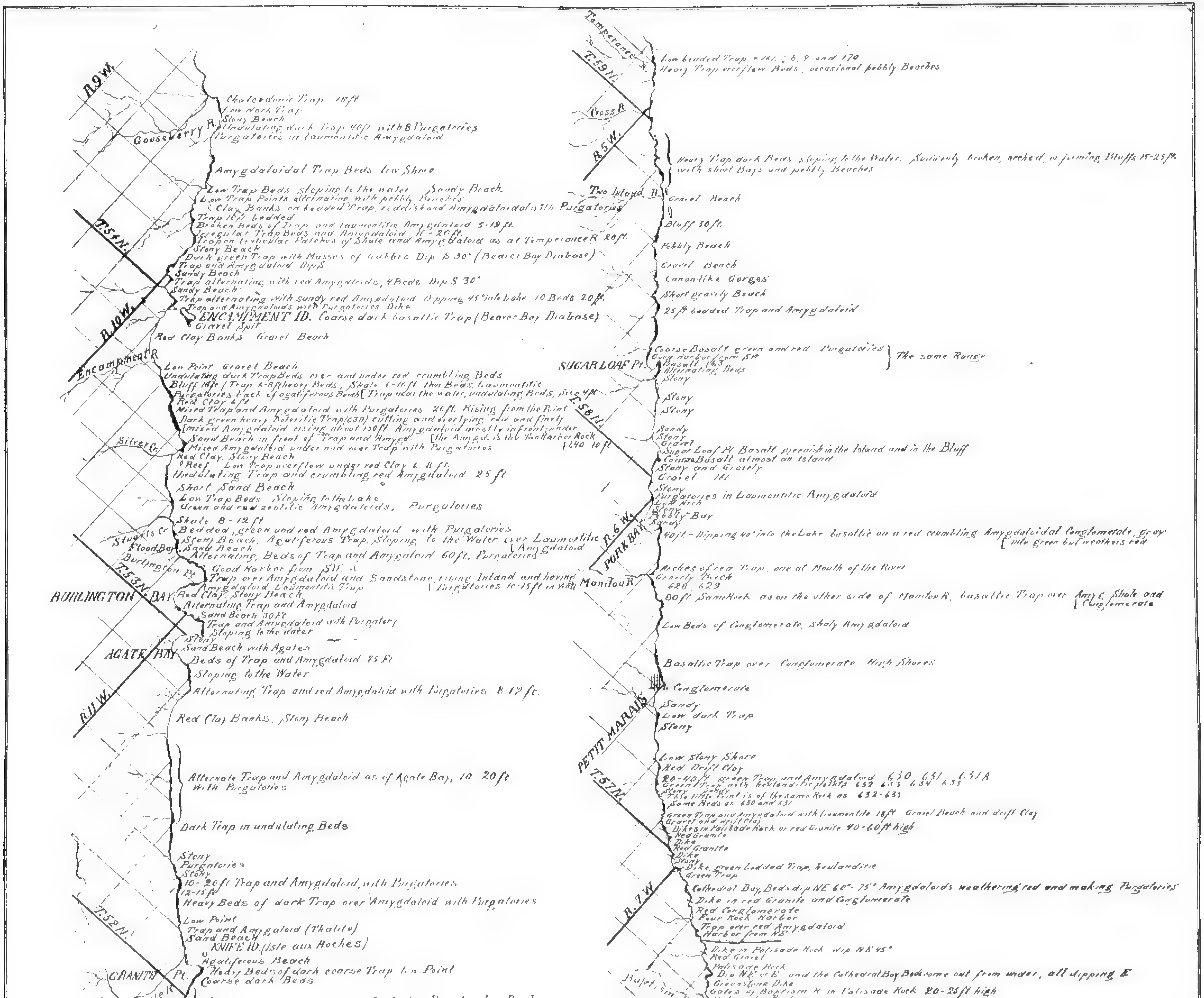
From Rice's point eastward the line of the lake shore obliquely crosses their outcropping edges, and gradually ascends in the series to the eastern limit of the plate. There is first a phase of the gabbro, which Irving called "orthoclase gabbro,"

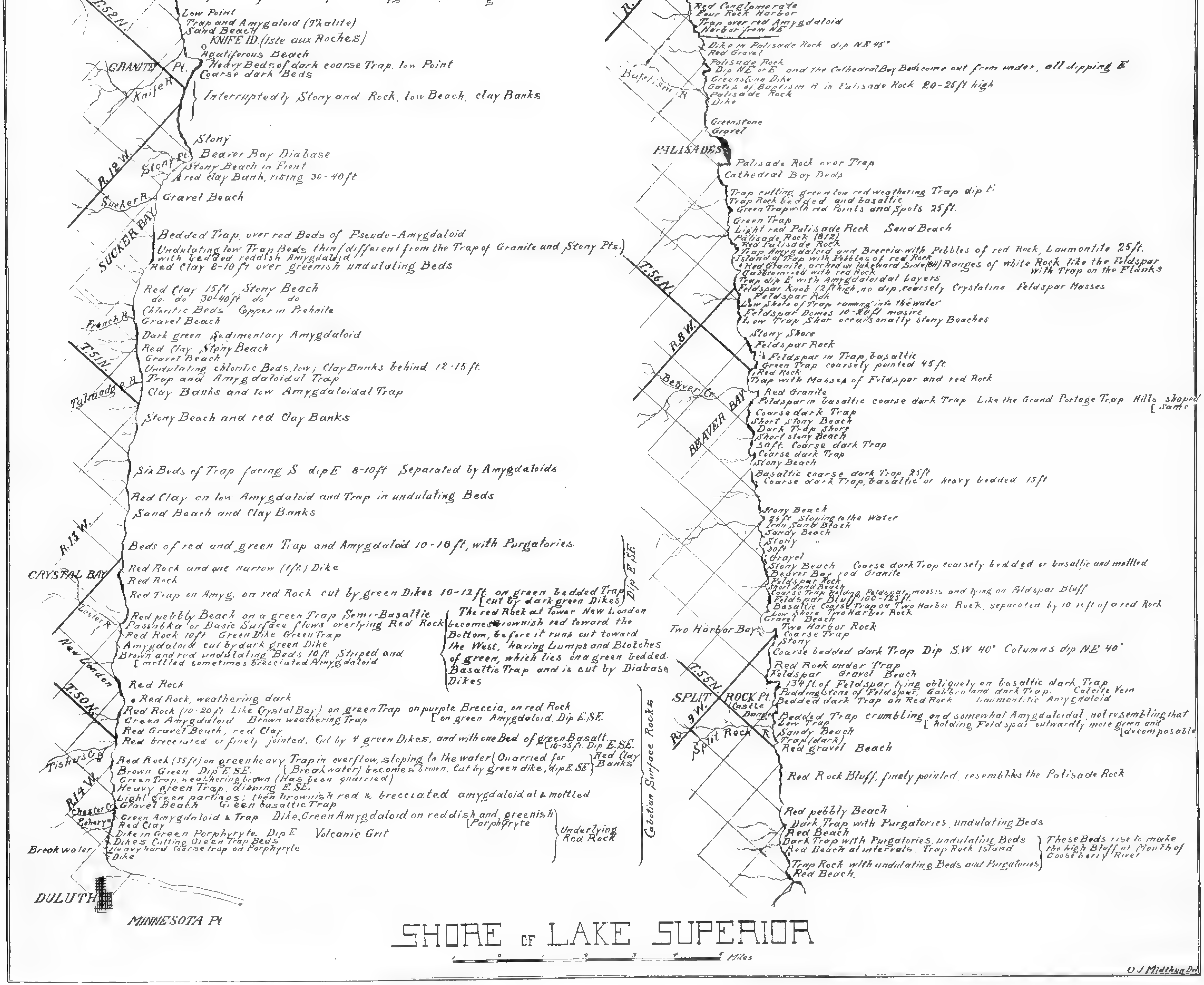
due to the close intermixture of the basic and acid elements. The gabbro also is found to present a curious manner of disintegration. It is changed into a mass of more or less globular pieces from one to three inches in diameter, represented by the photograph (figure 1, plate P). At points farther west these pieces are much coarser (No. 1D). They were noted at a point between the Union depot and the old quarry opened by T. M. Newson. Then succeeds toward the east a considerable thickness of compact, brownish-red, often porphyritic surface-rocks which are basic, or sub-basic, their upper surfaces becoming amygdaloidal. They are often variegated with red, especially by red feldspars disseminated through them. Sudden changes and overlapping irregularities characterize the structural succession. At times a fluidal surface is exposed; again a clastic stratum is intercalated, resembling a brown sandrock. These rocks are all split into numerous thin sheets parallel with their general dip (E. SE.), which often gives them the aspect of shales. The fragmental portions are tuffaceous, though still containing angular quartz grains.* The red rock that occurs in East Duluth and at New London (Nos. 55, 55A, 56, 58, 60, etc.) rises, in the form of a perpendicular or sometimes overhanging cliff, to the hight of ten to twenty-five feet from the water. It is more easily destroyed by the waves and by the ice, owing to its close jointing. This is sometimes porphyritic with bipyramidal quartzes and anorthoclase, and exhibits a fluidal structure.

Various porous, amygdaloidal and brecciated conditions occur eastward from New London. Sometimes the bedding is suddenly flexed and stands for a short distance nearly vertical, indicating strong dynamic pressure since the strata were formed.† Still farther east, and reaching to French river, is much brown diabase, which is rather firm, but bedded, amygdaloidal and easily disintegrated. At French river this holds prehnite and native copper, and once was explored by shafting, with hope of discovering copper in paying quantity. East of this the rock becomes heavily bedded and darker, the joints being lined with heulandite. The rock at the mouth of Knife river, and forming Knife island, is also a surface diabase, sometimes compact and sometimes vesicular. It rises from the water at the east side of Sucker bay, and shows numerous irregular cavities in which are accumulated calcite, quartz and thalite, the last (No. 91 B) a peculiar mineral resembling saponite.

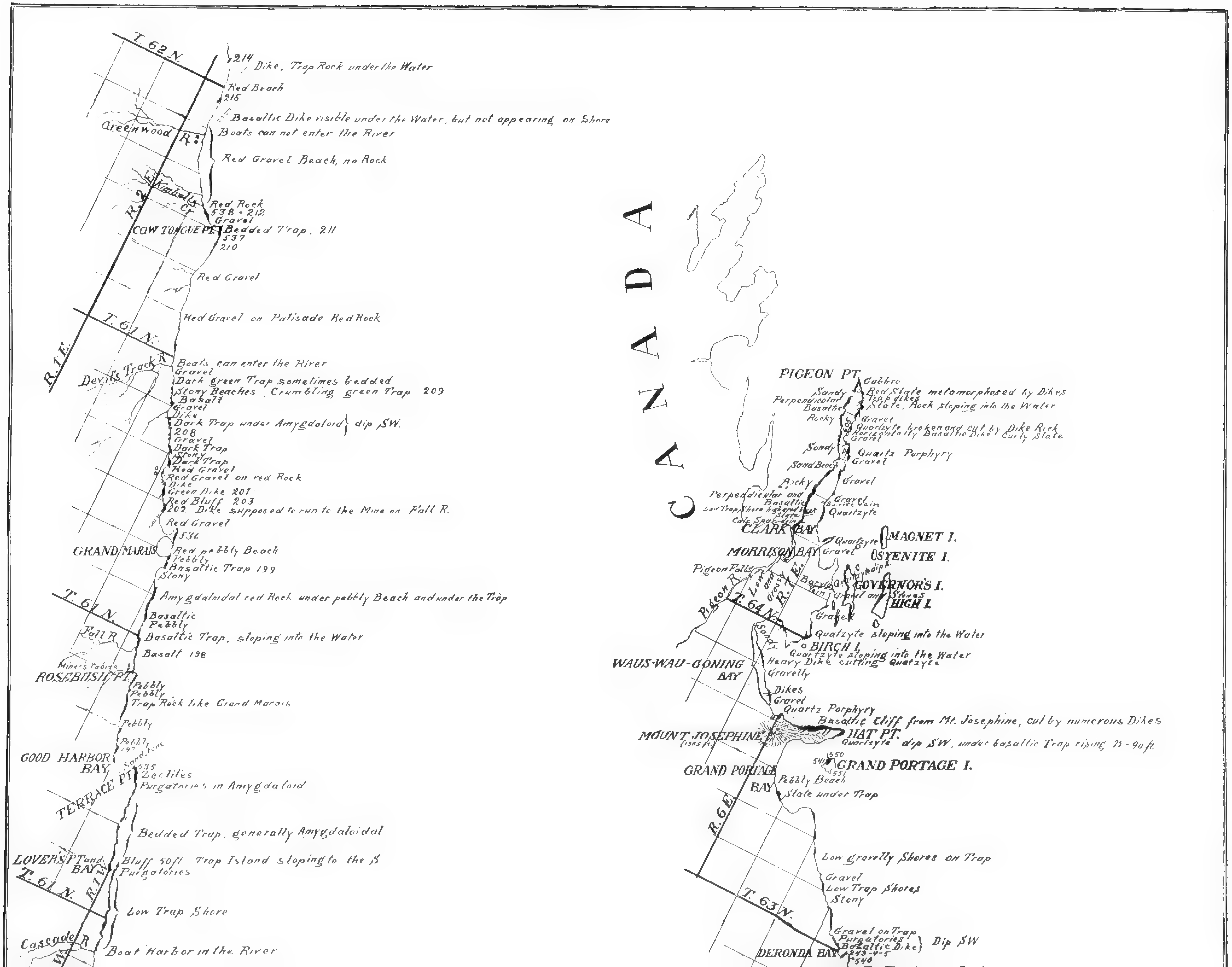
The Manitou. The only representative of the Manitou igneous rocks that can be recognized at Duluth is the dikes that cut these surface flows. Their direction is usually about north and south, and there are many of them. They are of diabase, dark-green or black, and frequently show a horizontal basaltic structure, indicating the loss of heat into the adjoining older rocks. If these diabase dikes originally reached the natural surface and there overflowed, they must have formed a series of

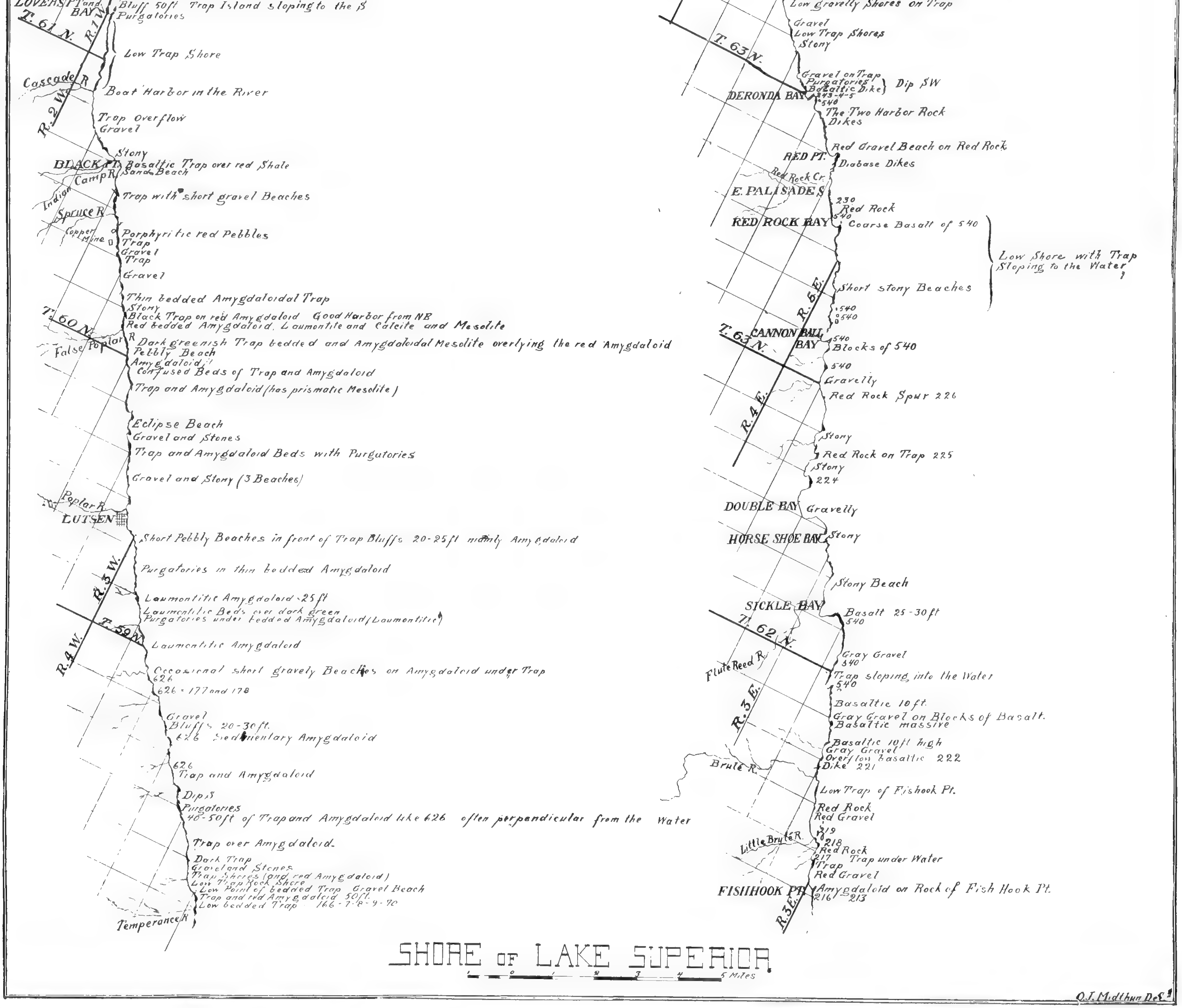
* These alternations are described more in detail in the *Ninth Annual Report*, pp. 11 to 24.
† See illustration of this structure in chapter xxxi.


R.9W.
Gooseberry R.
Chalcedonic Trap 10 ft
Low dark Trap
Stony Beach
Undulating dark Trap 40 ft with 8 Purgatories
Purgatories in laumontitic Amygdaloid
Amygdaloidal Trap Beds low Shore
Low Trap Beds sloping to the water Sandy Beach.
Low Trap Points alternating with pebbly Beaches
Clay Banks on bedded Trap, reddish and Amygdaloidal with Purgatories
Trap 10 ft bedded
Broken Beds of Trap and laumontitic Amygdaloid 5-12 ft.
Irregular Trap Beds and Amygdaloid 10-20 ft.
Trap on lenticular Patches of Shale and Amygdaloid as at Temperance R. 20 ft.
Stony Beach
Dark green Trap with Masses of Gabbro Dip S 30° (Beaver Bay Diabase)
Trap and Amygdaloid Dip S
Sandy Beach
Trap alternating with red Amygdaloids, 4 Beds Dip S 30°
Sandy Beach
Trap alternating with sandy red Amygdaloid dipping 45° into Lake, 10 Beds 20 ft.
Trap and Amygdaloids with Purgatories Dike
ENCAMPMENT ID. Coarse dark basaltic Trap (Beaver Bay Diabase)
Gravel Spit
Red Clay Banks Gravel Beach
T.54N.
R.10W.
Encampment R.
Low Point Gravel Beach
Undulating dark Trap Beds over and under red crumbling Beds
Bluff 18 ft (Trap 6-8 ft heavy Beds, Shale 6-10 ft thin Beds, laumontitic
Purgatories back of agatiferous Beach [Trap near the water, undulating Beds, Seen 4 ft
Red Clay 6 ft
Mixed Trap and Amygdaloid with Purgatories 20 ft. Rising from the Point
Dark green heavy Doleritic Trap (639) cutting and overlying red and finely
[mixed Amygdaloid rising about 150 ft Amygdaloid mostly in front; under
Sand Beach in front of Trap and Amygd. [the Amygd. is the Two Harbor Rock
Mixed Amygdaloid under and over Trap with Purgatories [640 10 ft
Silver Cr.
Red Clay, Stony Beach
Reef Low Trap overflow under red Clay 6 8 ft.
Undulating Trap and crumbling red Amygdaloid 25 ft
Short Sand Beach
Low Trap Beds Sloping to the Lake
Green and red zeolitic Amygdaloids, Purgatories
Shale 8-12 ft
Bedded, green and red Amygdaloid with Purgatories
Stony Beach, Agatiferous Trap, Sloping to the Water over Laumontitic Amygdaloid
Sand Beach
Alternating Beds of Trap and Amygdaloid 60 ft, Purgatories
Stuarts Cr.
Flood Bay
Burlington Pt.
T.53N.
Good Harbor from SW.
Trap over Amygdaloid and Sandstone, rising Inland and having Purgatories 10-15 ft in Wall
Amygdaloid Laumontitic Trap
BURLINGTON BAY
Red Clay, Stony Beach
Alternating Trap and Amygdaloid
Sand Beach 30 ft
Trap and Amygdaloid with Purgatory
Sloping to the water
Stony
Sand Beach with Agates
AGATE BAY
Beds of Trap and Amygdaloid 75 Ft
Sloping to the Water
R.11W.
Alternating Trap and red Amygdaloid with Purgatories 8-12 ft.
Red Clay Banks, Stony Beach
Alternate Trap and Amygdaloid as of Agate Bay, 10 20 ft
with Purgatories
Dark Trap in undulating Beds
Stony
Purgatories
Stony
10-20 ft Trap and Amygdaloid, with Purgatories
12-15 ft
Heavy Beds of dark Trap over Amygdaloid with Purgatories
T.52N.
Low Point
Trap and Amygdaloid (Thalite)
Sand Beach
KNIFE ID. (Isle aux Roches)
Agatiferous Beach
GRANITE Pt.
Heavy Beds of dark coarse Trap low Point
Coarse dark Beds
Temperance R.
T.59N.
Low bedded Trap 161, 168, 169 and 170
Heavy Trap overflow Beds, occasional pebbly Beaches
Cross R.
R.5W.
Heavy Trap dark Beds sloping to the Water. Suddenly broken, arched, or forming Bluffs 15-25 ft.
with short Bays and pebbly Beaches
Two Island R.
Gravel Beach
Bluff 30 ft.
Pebbly Beach
Gravel Beach
Canon-like Gorges
Short gravely Beach
25 ft bedded Trap and Amygdaloid
Coarse Basalt green and red Purgatories
Good Harbor from SW
Basalt 163
Alternating Beds
Stony
The same Range
SUGAR LOAF Pt.
T.58N.
Stony
Stony
Sandy
Stony
Gravel
Sugar Loaf Pt Basalt greenish in the Island and in the Bluff
Coarse Basalt almost an Island
Stony and Gravely
Gravel 161
Stony
Purgatories in Laumontitic Amygdaloid
Low Arch
Stony
Pebbly Bay
Sandy
R.6W.
PORK BAY
40 ft. - Dipping 40° into the Lake basaltic on a red crumbling Amygdaloidal Conglomerate, gray into green but weathers red
Arches of red Trap, one at Mouth of the River
Gravely Beach
628 629
Manitou R.
80 ft Same Rock as on the other side of Manitou R, basaltic Trap over Amyg. Shale and Conglomerate
Low Beds of Conglomerate, shaly Amygdaloid
Basaltic Trap over Conglomerate High Shores
Conglomerate
Sandy
Low dark Trap
Stony
PETIT MARAIS
Low stony Shore
Red Drift Clay
20-40 ft green Trap and Amygdaloid 630, 631, 631 A
Green Trap with heulanditic points 632 633 634 635
Stony Sandy
This little Point is of the same Rock as 632-635
Same Beds as 630 and 631
T.57N.
Green Trap and Amygdaloid with Laumontite 18 ft. Gravel Beach and drift Clay
Gravel and drift Clay
Dikes in Palisade Rock or red Granite 40-60 ft high
Red Granite
Dike
Red Granite
Dike
Stony
Dike, green bedded Trap, heulanditic
Green Trap
R.7W.
Cathedral Bay, Beds dip NE 60°-75° Amygdaloids weathering red and making Purgatories
Dike in red Granite and Conglomerate
Red Conglomerate
Four Rock Harbor
Trap over red Amygdaloid
Harbor from NE
Dike in Palisade Rock dip NE 45°
Red Gravel
Palisade Rock
Dip NE or E and the Cathedral Bay Beds come out from under, all dipping E
Greenstone Dike
Gates of Baptism R in Palisade Rock 20-25 ft high
Baptism R.



T.52 N.
Low Point
Trap and Amygdaloid (Thalite)
Sand Beach
KNIFE ID. (Isle aux Roches)
Agatiferous Beach
GRANITE Pt.
Heavy Beds of dark coarse Trap. low Point
Coarse dark Beds
Knife R.
Interruptedly Stony and Rock, low Beach, clay Banks
Stony
Beaver Bay Diabase
Stony Pt.
Stony Beach in Front
A red clay Bank, rising 30-40 ft
R. 12 W.
Sucker R.
Gravel Beach
SUCKER BAY
Bedded Trap over red Beds of Pseudo-Amygdaloid
Undulating low Trap Beds thin (different from the Trap of Granite and Stony Pts.)
with bedded reddish Amygdaloid
Red Clay 8-10 ft over greenish undulating Beds
Red Clay 15 ft, Stony Beach
do. do 30-40 ft do do
Chloritic Beds Copper in Prehnite
Gravel Beach
French R.
Dark green Sedimentary Amygdaloid
Red Clay Stony Beach
T. 51 N.
Gravel Beach
Undulating chloritic Beds, low; Clay Banks behind 12-15 ft.
Trap and Amygdaloidal Trap
Talmadge R.
Clay Banks and low Amygdaloidal Trap
Stony Beach and red Clay Banks
Six Beds of Trap facing S dip E 8-10 ft. Separated by Amygdaloids
Red Clay on low Amygdaloid and Trap in undulating Beds
Sand Beach and Clay Banks
R. 13 W.
Beds of red and green Trap and Amygdaloid 10-18 ft, with Purgatories.
CRYSTAL BAY
Red Rock and one narrow (1 ft.) Dike
Red Rock
Red Trap on Amyg. on red Rock cut by green Dikes 10-12 ft. on green bedded Trap
[cut by dark green Dikes
Dip E SE
Lester R.
Red pebbly Beach on a green Trap Semi-Basaltic
Passabka or Basic Surface flows overlying Red Rock
Red Rock 10 ft Green Dike Green Trap
Amygdaloid cut by dark green Dike
Brown and red undulating Beds 10 ft Striped and
[mottled sometimes brecciated Amygdaloid
The red Rock at lower New London becomes Brownish red toward the Bottom, before it runs out toward the West, having Lumps and Blotches of green, which lies on a green bedded Basaltic Trap and is cut by Diabase Dikes
New London
T. 50 N.
Red Rock
Red Rock, weathering dark
Red Rock (10-20 ft Like Crystal Bay) on green Trap on purple Breccia, on red Rock
Green Amygdaloid Brown weathering Trap
[on green Amygdaloid, Dip E.SE.
Red Gravel Beach, red Clay
Red brecciated or finely jointed. Cut by 4 green Dikes, and with one Bed of green Basalt.
[10-35 ft. Dip E.SE.
Fishers Cr.
Red Rock (35 ft) on green heavy Trap in overflow, sloping to the water (Quarried for
Brown Green Dip E.SE. [Breakwater) becomes brown. Cut by green dike, dip E.SE.
Red Clay Banks
Green Trap, weathering brown (Has been quarried)
R. 14 W.
Heavy green Trap, dipping E.SE.
Light green partings; then brownish red & brecciated amygdaloidal & mottled
Chester Cr.
Gravel Beach. Green basaltic Trap
Tischers Cr.
Green Amygdaloid & Trap Dike, Green Amygdaloid on reddish and greenish
[Porphyryte
Red Clay
Dike in Green Porphyryte Dip E Volcanic Grit
Dikes Cutting Green Trap Beds
Underlying Red Rock
Breakwater
Heavy hard Coarse Trap on Porphyryte
Dike
Cabotian Surface Rocks
DULUTH
MINNESOTA Pt
Red Conglomerate
Four Rock Harbor
Trap over red Amygdaloid
Harbor from NE
Dike in Palisade Rock dip NE 45°
Red Gravel
Palisade Rock
Dip NE or E and the Cathedral Bay Beds come out from under, all dipping E
Baptism R.
Greenstone Dike
Gates of Baptism R in Palisade Rock 20-25 ft high
Palisade Rock
Dike
Greenstone
Gravel
PALISADES
Palisade Rock over Trap
Cathedral Bay Beds
Trap cutting green low red weathering Trap dip E
Trap Rock bedded and basaltic
Green Trap with red Points and Spots 25 ft.
Green Trap
Light red Palisade Rock Sand Beach
Palisade Rock (812)
Red Palisade Rock
Trap Amygdaloid and Breccia with Pebbles of red Rock, Laumontite 25 ft.
Island of Trap with Pebbles of red Rock
Red Granite, arched on lakeward Side (811) Ranges of white Rock like the Feldspar
Gabbromixed with red Rock with Trap on the Flanks
T. 56 N.
Trap dip E with Amygdaloidal Layers
Feldspar Knob 12 ft high, no dip, coarsely Crystaline Feldspar Masses
Feldspar Rock
Low Shore of Trap running into the water
Feldspar Domes 10-20 ft massive
Low Trap Shore occasionally stony Beaches
Stony Shore
R. 8 W.
Feldspar Rock
Feldspar in Trap, basaltic
Green Trap coarsely pointed 45 ft.
Red Rock
Trap with Masses of Feldspar and red Rock
Beaver Cr.
Red Granite
Feldspar in basaltic coarse dark Trap Like the Grand Portage Trap Hills shaped [same
BEAVER BAY
Coarse dark Trap
Short stony Beach
Dark Trap Shore
Short stony Beach
30 ft. Coarse dark Trap
Coarse dark Trap
Stony Beach
Basaltic coarse dark Trap 25 ft
Coarse dark Trap, basaltic or heavy bedded 15 ft
Stony Beach
25 ft Sloping to the water
Iron Sand Beach
Sandy Beach
Stony "
30 ft
Gravel
Stony Beach Coarse dark Trap coarsely bedded or basaltic and mottled
Beaver Bay red Granite
Feldspar Rock
Short Sand Beach
Coarse Trap holding Feldspar masses and lying on Feldspar Bluff
Feldspar Bluff 100-125 ft.
Basaltic Coarse Trap on Two Harbor Rock, separated by 10-15 ft of a red Rock
Low Shore Two Harbor Rock
Gravel Beach
Two Harbor Bay
Two Harbor Rock
Coarse Trap
Stony
Coarse bedded dark Trap Dip S.W 40° Columns dip NE 40°
Red Rock under Trap
Feldspar Gravel Beach
T. 55 N.
134 ft. of Feldspar lying obliquely on basaltic dark Trap
SPLIT ROCK Pt.
Pudding stone of Feldspar Gabbro and dark Trap. Calcite Vein
Castle Danger
Bedded dark Trap on Red Rock Laumontitic Amygdaloid
R. 9 W.
Bedded Trap crumbling and somewhat Amygdaloidal, not resembling that
Low Trap [holding Feldspar outwardly more green and
Split Rock R.
Sandy Beach [decomposable
Trap (dark)
Red gravel Beach
Red Rock Bluff, finely pointed, resembles the Palisade Rock
Red pebbly Beach
Dark Trap with Purgatories, undulating Beds
Red Beach
Dark Trap with Purgatories, undulating Beds
Red Beach at intervals. Trap Rock Island
These Beds rise to make the high Bluff at Mouth of Gooseberry River
Trap Rock with undulating Beds and Purgatories
Red Beach.
SHORE OF LAKE SUPERIOR
1 0 1 2 3 4 5 Miles
O J Midthun Del.


T. 62 N.
214 Dike, Trap Rock under the Water
Red Beach
215
Basaltic Dike visible under the Water, but not appearing on Shore
Greenwood R.
Boats can not enter the River
Red Gravel Beach, no Rock
R. 2 E.
Kimballs Cr.
Red Rock
538 - 212
Gravel
COW TONGUE PT.
Bedded Trap, 211
537
210
Red Gravel
Red Gravel on Palisade Red Rock
T. 61 N.
R. 1 E.
Devil's Track R.
Boats can enter the River
Gravel
Dark green Trap sometimes bedded
Stony Beaches, Crumbling green Trap 209
Basalt
Gravel
Dike
Dark Trap under Amygdaloid dip SW.
208
Gravel
Dark Trap
Stony
Dark Trap
Red Gravel
Red Gravel on red Rock
Dike
Green Dike 207
Red Bluff 203
202 Dike supposed to run to the Mine on Fall R.
Red Gravel
536
GRAND MARAIS
Red pebbly Beach
Pebbly
Basaltic Trap 199
Stony
Amygdaloidal red Rock under pebbly Beach and under the Trap
T. 61 N.
Basaltic
Pebbly
Fall R.
Basaltic Trap, sloping into the Water
Basalt 198
ROSEBUSH PT.
Pebbly
Pebbly
Trap Rock like Grand Marais
Pebbly
Pebbly
GOOD HARBOR BAY
535
Zeolites
Purgatories in Amygdaloid
TERRACE PT.
Bedded Trap, generally Amygdaloidal
LOVERS PT and BAY
Bluff 50 ft Trap Island sloping to the S
Purgatories
T. 61 N.
R. 1 W.
Low Trap Shore
Cascade R.
Boat Harbor in the River
CANADA
PIGEON PT.
Gabbro
Red Slate metamorphosed by Dikes
Trap dikes
Slate, Rock sloping into the Water
Sandy
Perpendicular
Basaltic
Rocky
Gravel
Quartzyte broken and cut by Dike Rock
Horizontally Basaltic Dike
Curly Slate
Gravel
Sandy
Quartz Porphyry
Gravel
Sand Beach
Gravel
Rocky
Perpendicular and Basaltic
Low Trap Shore
Slate
Calc Spar Vein
Gravel
Barite Vein
Quartzyte
CLARK BAY
Quartzyte
MAGNET I.
MORRISON BAY
Gravel
OSYENITE I.
Pigeon Falls
Pigeon R.
Low and Grassy
R. 7 E.
Baryta Vein
GOVERNOR'S I.
Gravel and Stones
HIGH I.
T. 64 N.
Gravel
Sandy
Quartzyte sloping into the Water
BIRCH I.
Quartzyte sloping into the Water
WAUS-WAU-GONING BAY
Heavy Dike cutting Quartzyte
Gravelly
Dikes
Gravel
Quartz Porphyry
Basaltic Cliff from Mt. Josephine, cut by numerous Dikes
MOUNT JOSEPHINE (1305 ft.)
HAT PT.
Quartzyte dip SW, under basaltic Trap rising 75 - 90 ft.
550
541
534
GRAND PORTAGE I.
GRAND PORTAGE BAY
Pebbly Beach
Slate under Trap
R. 6 E.
Low gravelly Shores on Trap
Gravel
Low Trap Shores
Stony
T. 63 N.
Gravel on Trap
Purgatories
Basaltic Dike
243-4-5
546
Dip SW
DERONDA BAY



SHORE OF LAKE SUPERIOR

basic lavas which would have been very much like those that now form the lake shore. Such may still exist farther to the south, buried under the water of the lake, and perhaps under cotemporary fragmental conglomerates and sandstones. Such fragmentals are supposed to be those seen in the St. Louis valley above Fond du Lac, although at that point no actual Manitou lavas exist—except as debris forming eruptive conglomerates.

The drift. In general the area represented by plate 66 is deeply buried under glacial drift. The valleys have been occupied formerly by enormously larger streams, with the exception of that portion of the St. Louis valley below Carlton and of the small streams flowing southeastward into the lake below the level of about 500 feet above the lake. These have excavated their channels in the drift since the retirement of lake Superior from about that altitude, and there is no known reason to suppose that these streams have been very much larger since that event. Above that level, however, the valleys are all subject to the expansion which is characteristic of valleys excavated during the prevalence or at the final retirement of the ice-sheet, when surface drainage was more copious and more violent.

There is an extensive flat and often swampy region lying to the northwest from the Cloquet river, drained by the White Face, the St. Louis and the Floodwood rivers. In general this occupies the area between two morainic belts. The southern morainic belt extends from the gabbro range westward and southwestwardly across Carlton county; and the northern belt is about coincident with the Giant's range (of granite) which crosses the northern part of St. Louis county.

While it is probable that during the acme of the Pleistocene glaciation the general direction of ice-motion was toward the south, it is also probable that after the formation of the Giant's range moraine, and perhaps as late as after the formation of the more southerly moraine mentioned, the ice dwindled to the size of a merely local lobe occupying the basin of lake Superior and moving southwestwardly. Indeed, this latter movement is well established by the direction of glacial striæ about Duluth and by the direction of transport of gabbro and Keweenawan debris. This is further elucidated in the chapter devoted to Carlton county (plate 56). It is yet unknown how extensive was this later lobe of the retiring continental glacier. There are some indications that its northwestern border extended so far west as to include, at first at least, the whole of this plate south of the St. Louis river.* At any rate there came a time, which was probably many centuries in duration, when it turned the St. Louis river from access to the lake Superior basin, as explained in the report on Carlton county, and caused it to deliver its waters into the Kettle river, and thus into the St. Croix and to the Mississippi valley at Hast-

*There is reason to believe that the lake Superior basin was occupied by a much greater lobe of the retiring ice-sheet than is here suggested, and that it extended over several counties toward the west. Consult the discussion of the moraines of southern Beltrami county by J. E. Todd, chapter vii.

ings. It was during this flooded condition of the St. Louis and its upper tributaries that took place those events which gave to the northwestern part of this area its present topographic and surface characters. There were seasons when a large lake, or a series of shallow lakes, covered most of this area, and some of them perhaps were permanent; indeed, at the present time these muskegs are half-filled lake basins on whose surfaces floats a peaty, shaking bog. The surfaces are not everywhere level, though flat. Through these bogs is an obstructed, slow drainage toward the rivers, and thence toward the south. Generally, these bogs are not deep. The drift surface is close beneath, and consists frequently of very fine sand, rarely of clay, while in occasional island-like patches, characterized by larger growth of trees or even by different species of trees, the underlying unmodified till protrudes above the muskeg surface. The northern and southern borders of this swampy tract are formed by the gradual elevation of the till-covered surface. Throughout this flat country the immediately underlying drift consists, for the most part, of washed and perhaps wind-blown sands which are of a light color, varying to fine, sandy clays. This character of the immediate surface also rises, about the borders of the swamp, considerably above the surface of the swamp, and is covered with a rich forest. It is then a kind of loam or lœss, and possesses the agricultural qualities that mark the lœss of the Mississippi valley. That the surface deposits of this tract antedate, in part at least, the ice-lobe that occupied the lake Superior basin is indicated by phenomena reported by Mr. Spurr: "Between Grand lake and the Cloquet river, in numerous cases cuts show a veneer of till, with many boulders (chiefly anorthosyte and other rocks characteristic of the Keweenawan province), which covers an apparently deep deposit of fine, perfectly stratified sand." This is on the western fringe of the lateral moraine of the lake Superior ice-lobe. At the time this took place the appearances all along the ice-border may have been somewhat like those described by Mr. H. P. Cushing at the terminal margin of the Muir glacier when that glacier is seen to be overriding stratified drift deposits.*

Pleistocene changes of the level of lake Superior at Duluth. At a later stage of the retreating ice a lake was formed about its border, which had its outlet in Carlton county. This outlet changed its place from time to time as lower outlets were uncovered, as mentioned in the description of Carlton county, forming beaches at varying altitudes, until the lake was finally drained toward the east. These beaches are still visible, the highest one being at 534 feet above the lake. Subsequently, on the entire withdrawal of the glacier from the continent, there was a return of the lake's water toward the west, causing the flooding of some territory that had been dry land, and the submergence of some of the lowest beaches. The lowest beach,

* *American Geologist*, vol. viii, p. 207, plate III.

Fig. 1. Cut in a Gravel Bank, Duluth, Showing the Stratification of the Old Beach. (p. 219.)

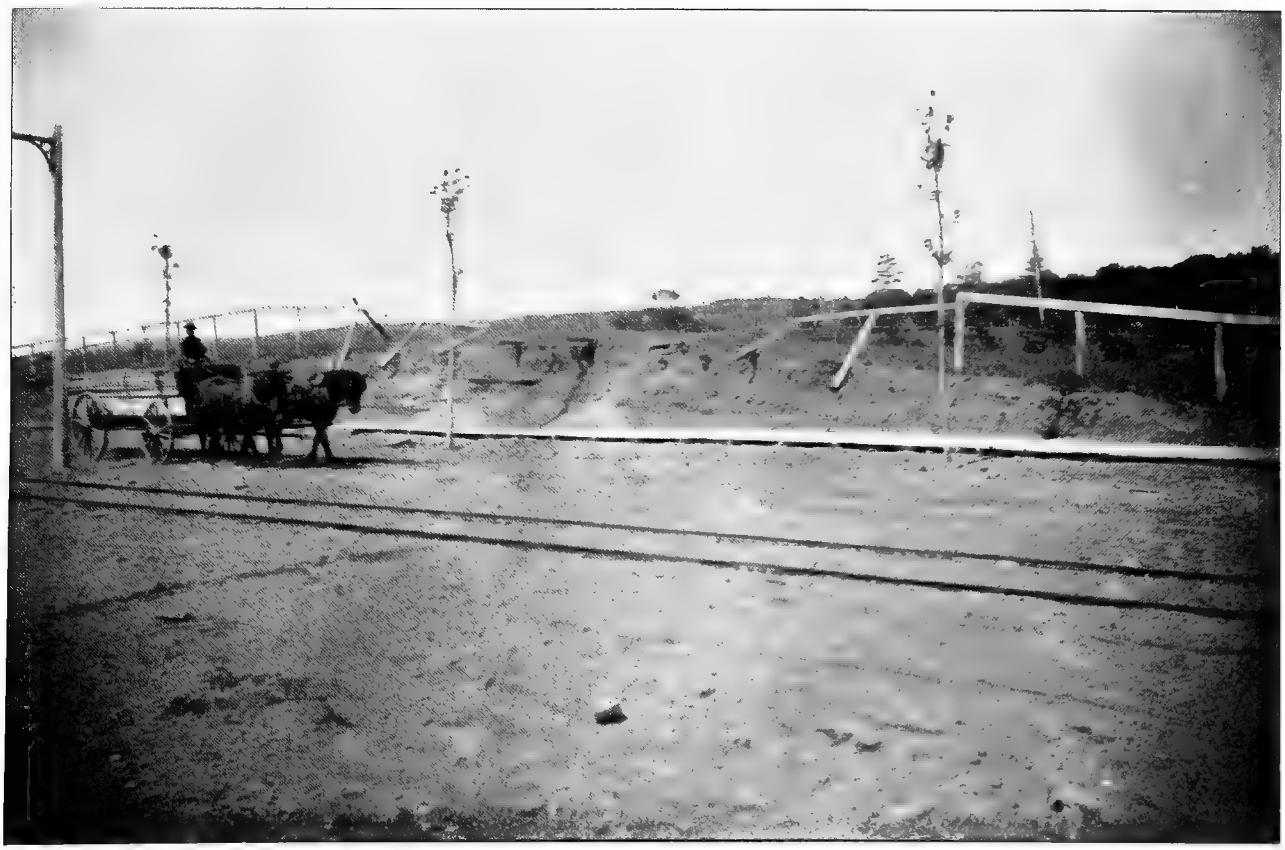


Fig. 2. Gravel Cut; Section Across the Beach at Hardy's Schoolhouse, About One Mile West of the East Limit of Duluth, on the Electric Railway. (p. 221.)

Fig. 1. Globular Disintegration of the Gabbro, Michigan St., Duluth. (p. 580.)

Fig. 2. Lake Terrace with Sea Cliff in the Background; End of Ninth Ave., W. Duluth; Partially Masked by Subsequent Wash at the Right. (p. 219.)

on being traced westwardly, appears, according to Mr. Upham, to run below the lake level at Duluth, about twenty-five feet.* The water of this lake (lake Nemadji), even allowing for subsequent westward tilling, must have covered the region to the west from Duluth as far as to Carlton, in Carlton county, and must have received the waters of the St. Louis river at that elevation. That place is now 481 feet above the lake, but must have stood at 500 or 525 feet above the surface of the lake at the date of formation of this beach.

Dr. A. C. Lawson has given† some details of the phenomena of these changes at Duluth as follows:

West Duluth. On the hills of the city of Duluth a very clear and excellent registration of some of the higher stages of the lake may be observed. The city, as is well known, is being built upon the steep lakeward slope of a massive, rounded range of coarsely crystalline gabbro, which within the city limits rises to an elevation of probably 800 feet above the present level of the lake. On the upper portion of this slope the topography is such that it has been found a convenient and easy matter to construct, as part of the general embellishment of the city, a magnificent carriage drive around the brow of the hill. This carriage drive follows a contour line at an average elevation of perhaps 470 feet, and is known as the Lake View terrace, or Terrace boulevard.

It requires but a cursory inspection to see that the particular phase of the topography, which has suggested and made easy the construction of this Lake View terrace, is due to the imposing upon the steep and rocky hill-side of a feature which has been developed along a former shore line of the lake. This feature consists of a pronounced natural terrace or shelf facing the open lake. It varies considerably in width, being narrow where it rounds the shoulders of the hills and widening out very much in the bays and recesses. It has a gentle but constant slope lakeward, and ends rather abruptly on its outer edge, dropping away into the general steep slope of the hill. The back of the terrace is limited usually by the rounded glaciated forms which characterize the upper portion of the gabbro mass. These rounded forms at the back of the terrace are in places replaced, however, by vertical cliffs of gabbro, with large blocks which have fallen from its face scattered about the rear of the terrace, and partly imbedded in it. This vertical face of rock, with its talus of angular blocks, represents undoubtedly a "sea-cliff," and is, like the terrace, a product of shore action. An example of such sea-cliff may be seen near the upper end of Ninth avenue west (plate P, figure 2).

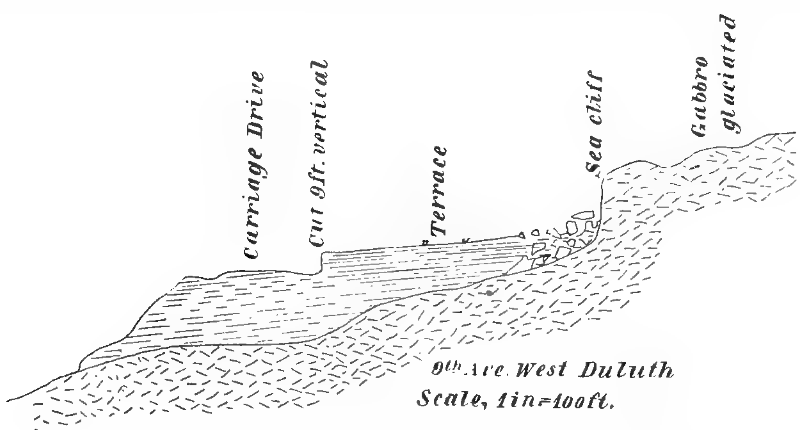


FIG. 21. SECTION AT THE HEAD OF NINTH AVENUE WEST, DULUTH.
Elevation of terrace, 476 feet.

The material of which the terrace is built consists of surf-rolled boulders, pebbles, gravel and sand. The arrangement of this material is well seen in the cuts which have been made at a few points in the construction of the drive. In the cut at the upper end of Ninth avenue west, about 150 feet in front of the sea-cliff just mentioned, the terrace has been sunk into so as to afford a vertical section of nine feet. The lower six feet of this section show sharply bedded gravel and sand with occasional boulders up to one foot in diameter (plate Q, figure 1). The upper three feet of the section, although composed of the same materials, is not distinctly bedded, but this obscuration of the stratification may be due to the action of vegetation. The strata intersect the vertical plane of the section usually in quite horizontal lines. At the south end of the cut, however, oblique bedding of alternating wedges of gravel and sand is well seen, the dip of these beds being 25° and less.

The relation of the various factors of the topography at the head of Ninth avenue west is illustrated in the diagrammatic section (figure 21, above).

*There is an extensive recent literature pertaining to the levels of the great lakes, and their changes in consequence of the retreat of the ice of the Pleistocene. The reader is referred to the investigations of Upham, Taylor, Gilbert, Spencer, Lawson, and others, published in the *American Geologist*, *American Journal of Science*, *Journal of Geology*, the *Bulletin of the Geological Society of America*, and in the reports of the Minnesota Survey.

† *Twentieth Report of Minnesota Survey*, for 1891.

The rear of the terrace in front of the sea cliff was found to be 475.9 feet above the lake. The structure of the terrace shows that while primarily it is a wave-cut feature, the cut shelf of rock and the slope below it are covered with current-sorted material which was probably brought down by minor drainage (plate P, figure 2).

Evidence of shore lines at lower levels in the western part of Duluth was not satisfactorily observed, although they will probably be found if looked for on the slopes between Duluth and Fond du Lac.

At a higher level, however, there is a great beach which spans an embayment in the hill front and stretches continuously between the two shoulders of rock which are at the head of Sixth and Eighth avenues west, respectively. The Seventh avenue inclined railway, which was under construction at the time the examination was made, terminates on this beach, the crest of which was found to have an elevation of 534 feet. The presence of the beach is clearly revealed by the topography which it imposes upon the hillside. The contrast with the unaffected portions of the hill is striking. The horizontality of the beach crest is the feature which first attracts attention, the longitudinal profile of the beach with the rock on either side being not unlike that of the upper half of a dumb-bell, thus ⌒——⌒. The transverse profile shows the characteristic undulatory front slope of shingle beaches, the descent being by a succession of rounded steps. The same profile shows also a well marked lagoon hollow behind the beach. The ground plane shows that this lagoon hollow is entirely enclosed by the straight beach in front and by the rocky slopes of the hill on the sides and in the rear, so that the contour of its rim is roughly of the form of the letter D.

At the south end the beach has been quarried for road ballast, and there the material which enters into its composition, and the arrangement of the same, are readily observable. The material consists chiefly of pebbles and boulders, which range in size from two to six inches and have a prevailingly rounded form. There are a few large boulders up to two feet in diameter, and a good deal of finer gravel. Stratification is not discernible in the mass of the beach, and the pebbles and boulders are piled up in the irregular fashion so well exhibited by the living beaches of the lake. There was no longitudinal section which would permit of an observation as to the sorting of the material according to its relative coarseness. In the upper part of the beach there is some fine gravel and sand which shows a stratiform arrangement, but this is probably due to wash from the lagoon, since such drainage would doubtless have kept a way open for itself through the beach.

The undulatory front slope of the beach extends from its crest at an elevation of 534 feet down to the rear of the terrace already described at an elevation of 475.9 feet, and the relations seem to warrant the inference that the higher strand line is the older, and that the water subsided by stages till it arrived at the one marked by the Lake View terrace, where it remained constant for a sufficient length of time to evolve the striking feature of the topography, the terrace being in fact cut into the slope of the older and higher beach.

Duluth, Tenth avenue east. Near the head of Tenth avenue east, three distinctly marked strand lines are recognizable. The highest of these is a wave-built terrace of pebbles and boulders resting on a rocky slope and facing the open lake. Careful leveling established its elevation at 534.8 feet, which agrees within a foot with the altitude established by an entirely independent line of levels for the beach at the head of Seventh avenue west. From this elevation down to an altitude of 436.2 feet, or in round numbers a vertical distance of 100 feet, there is a continuous bank of beach material, comprising boulders, gravel and coarse sand, lying upon the slope of the hill. On the front of this great embankment there is a level terrace, which, while not very broad, is persistent, and on being traced southward is found to abut directly against the rocky slope at a place where the upper terrace is wanting. This second terrace was found to have at the rear an elevation of 473 feet, which again agrees very closely with the figures obtained for the rear of the Lake View terrace in West Duluth. The structure of the upper terrace is not revealed by any section; but below the 473-foot terrace there have been a number of excavations for road ballast, and in these it is seen that this lower part of the gravel bank is distinctly stratified, with a dip in the direction of the slope of the hill, but at a much less angle. There is a small ravine to the left of the higher terrace, and there is little doubt that the stream which flowed down this ravine supplied the material of which the whole of the 100-foot bank is constructed; and the development of the two terraces and the stratiform structure, seen below the second one, is probably explained by the following considerations:

The bedrock of the ravine is much lower than the upper terrace, and was so when the lake stood at the level at which the terrace was built. The ravine, after becoming itself filled with detritus to the level of the lake, would supply the material for the terrace, and besides this there would be much which would be carried down to the subaqueous slope and arranged by the various currents into strata. As the level of the lake subsided the ravine would be cleaned out, and its accumulations spread out on still lower slopes, also in bedded fashion. In this way the 100-foot bank of gravel, etc., stratified in its lower part, would have been accumulated. The lower strand line represents a stage in the recession of the water, at which, as in West Duluth, a second terrace was imposed upon the slope of the growing bank, partially cutting into the flanks of the upper terrace.

At the foot of the rather steeply inclined 100-foot bank of beach material, the slope suddenly changes and flattens out into a broad, gently inclined terrace in which no rock in place is seen. The rear of the terrace was found to have an altitude of 436.2 feet. Its surface is composed of a dark earth in which are imbedded scattered boulders, and it is covered with grass or timber so that its substructure is not apparent. On following the rear of this terrace northward beyond the gravel pits, it is found to abut against the *roches moutonnées* of the hill-side without the intervention of the gravel. The age of this terrace relatively to the gravel terraces above it is doubtful. It is uncertain whether the gravel bank rests upon the rear of this terrace or whether the terrace is imposed upon the lower flanks of the gravel bank. Owing to the absence of natural sections no ready answer presented itself to this question, and time was not taken to investigate it. It is possibly an older terrace, but evidence of this supposition is lacking.

Series 3. Hardy's schoolhouse. Near the eastern limits of Duluth, in the vicinity of Hardy's schoolhouse, there is a magnificent illustration of that phase of topography which is due to the development of a bar beach and delta deposit at the mouth of a valley, which has been the channel of a stream flowing into a lake at a level now abandoned. The altitude of the crest of the barrier beach was found to be 509.5 feet above the lake. Northward from it there extends a forest-clad, rock-walled valley about a mile wide at the mouth where spanned by the barrier beach. About the mouth of the valley are several isolated rocky hills which evidently formed islands in the lake when it stood at this high level. They rise from out of the beach formation or from the flat-lying delta deposits farther out which represent the shoals of the old lake bottom. The crest of the beach has a curvilinear form and extends in a southwesterly direction from the rocky knob at the schoolhouse, which stands at its northeast extremity, to the rocky hills which rise at the back of the city. In a general way it seems concave towards the valley, but it is by no means a simple ridge. It has a very extensive areal distribution, and while on the side it presents sections, as along the line of the electric tramway, which are simple lowly-arched ridges of beach material, towards the middle of the valley it spreads out and grades into a broad delta. The crest of the beach is higher than the valley bottom to the north of it, and also higher than the flat tract to the south. The section referred to on the line of the tramway near the schoolhouse is a cutting made in the construction of the road, and displays a vertical section of about six feet of evenly and obliquely bedded gravels, with some sands (plate Q, figure 2).

On the lower slopes of the eastern part of the city of Duluth, and for many miles northeastward along the coast, there are definite indications and suggestions of terraces when the land is viewed from a distance. There are two circumstances, however, which interfere with the recognition and location of these terraces at close quarters. The first of these is that the geological structure of this part of the coast is such that the strata dip lakeward at about the same angle as the slope of the terraces, so that the changes of inclination in the transverse profile are not sufficiently accentuated to permit of reliable determination of the line of the abutment of the terraces upon the hill-side. The second unfavorable circumstance is the prevalence of timber, which obscures the surface but allows the general effect of a terrace to be sometimes dimly apparent at a distance.

Mr. Upham has added the following further details of the beaches at Duluth: The upper limit of lacustrine action at Duluth and in its vicinity is marked by discontinuous beach deposits on the upper part of the steeply ascending bluffs at an altitude of 535 feet to 540 feet above the lake. In the recess between two projections of rock at the top of the Seventh avenue inclined railway, where the hight of this shore was determined by Dr. Lawson, it appears as a small terrace of sand and fine and coarse gravel, twelve to fifteen rods long and five rods wide. The verge of this flat surface is on the level of the railway station floor, and thence the terrace rises four or five feet to where it joins the till and rock slopes. In front the same gravel and sand fall off about twenty feet within a few rods and then spread out again in a similar lower and longer terrace, eight to ten rods wide, with its surface gently inclining lakeward, at 515 to 505 feet, approximately. These deposits were brought, partially by inflowing waters from above, being so far of delta character, and partially by shore currents, from wave erosion of the adjoining bluffs on each side, being for such portion more strictly beach accumulations. They mark stages of a lake whose mean levels here were about 535 and 510 or 515 feet above lake Superior.

Next below these shore lines is the most definite and persistent beach of the entire series. This was generally represented along the bluff face by a narrow beach terrace, or slight shelf, less steep than the slopes above and below it, so that its contour line, 470 to 475 feet above the present lake, has been used as the course of a driveway known as "the boulevard," which has been graded, and is much used for pleasure driving along an extent of four miles, above the principal part of the city of Duluth, from Miller's creek to Chester creek. Beyond these limits the boulevard is planned to be extended for distances of four miles more, both to the southwest and northeast, following the same altitude and shore line, giving a total length of twelve miles.

Lacustrine clays. About the west end of lake Superior are extensive beds of laminated clays. These are always superficially red, and in the immediate valley of the St. Louis river, as at Fond du Lac, and in the terraces that occur further east, that color prevails to the depth of several feet; but in the valley of the Nemadji, and and also at Wrenshall, in Carlton county, where extensive brick-making establishments are based on these clays, they are red only at the surface, becoming gray below at the depth of two to six feet. These clays were of course the result of the high-level stage of lake Superior at the closing up of the glacial epoch, and probably while the glacial drift of the region to the west and northwest was still subject to extensive wash and erosion by the high waters of the rivers and all their minutest tributaries.

Rocks collected in the area of this plate. Nos. 1–91C; 443–448; 511 516; 807–809; 850, 853–853B; 856, 857; 1540–1545; 1796–1806; 1942–1948; 1950–1954; 1966–1968.

Nos. 188S–202S.

Nos. 18M–20M; 36M, 37aM; 40M–46M.

Nos. 925G -929G.

CHAPTER X.

THE GEOLOGY OF THE NORTH PART OF ST. LOUIS COUNTY.

(PLATE 67.)

BY N. H. WINCHELL.

This large area includes a great variety of topography and of geology, involving many of the most important and complicated problems.* Its geological range is from the Archean gneisses and granites to the gabbro and other eruptions of the Cabotian. It is crossed by both iron ranges and within it are exemplified the varied economic as well as structural problems pertaining to the iron ores.

In this chapter is given a general description of the whole area. The details of the geology of the most interesting and difficult, as well as the most important, portions will be found in connection with special plates, viz.: of the region of Vermilion lake, the Vermilion Lake plate (No. 86); of the Mesabi Iron range, the Hibbing, Mountain Iron, McKinley, Partridge River and Dunka River plates (Nos. 73, 74, 75, 76, and 77). The economical questions connected with iron ranges are presented by H. V. Winchell, in a special chapter.

Topography and general features. Without entering into the geology, the following brief descriptions of the topographic features of the various towns of this plate will serve not only as a guide to the character of the country in general, but as a basis on which some generalizations can be made touching the distribution and nature of the drift deposits.

Special descriptions of the towns. The following notes are derived from the field-books of members of the survey who have examined the region. In some cases, especially in the region north and west of Vermilion lake, they are derived in part from the United States surveyors. The list begins at the lower right hand corner of the plate.

T. 55-12. The highest point on the Duluth and Iron Range railroad occurs in section 36, 1,744 feet above the sea, about one mile north of Highland, with a cut of twenty feet in morainic drift. Throughout this town are scattered many large boulders of gabbro, and these are sometimes disposed in low ridges rising from ten to thirty feet above the general level. These occur particularly in the east-central portion. The Cloquet river runs on grabbro in sections 19 and 30.

T. 55-13. The surface is characterized by alternating swamps and low ridges extending northeast and southwest, with grabbro boulders along the river.

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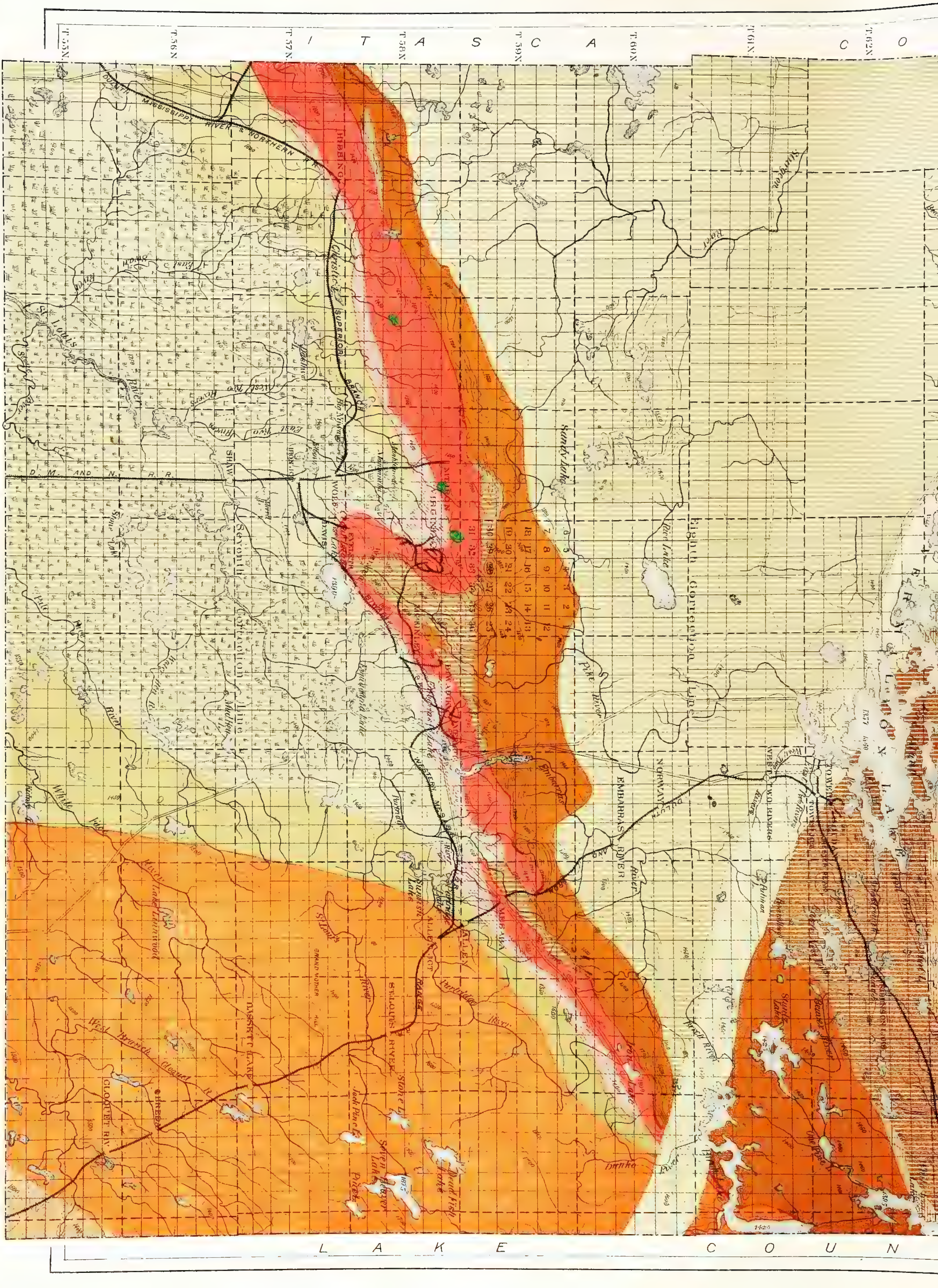
*The compilation of this description is based on field notes and published reports of nearly all members of the survey. The first field notes and first collections made were by the writer, who crossed this area diagonally from northeast to southwest in 1878, in making an extended reconnoissance from Grand Portage to the Mississippi river. This trip included a visit to the Mesabi iron working in T. 59-14. In 1884 another trip was made by the writer across the Mesabi range to Vermilion lake along the line of the Duluth and Iron Range railroad. The seasons of 1886 and 1887 were largely devoted to the examination of this area, the entire geological corps, consisting of three parties, having been engaged more or less. These parties were under the immediate direction of late Dr. Alexander Winchell, Dr. M. E. Wadsworth, and the writer. Mr. Horace V. Winchell made independent observations and reports in 1886, 1888 and 1891, including portions of this area, and Dr. U. S. Grant in 1888; the latter also examined the international boundary, cursorily, westward from the area examined in 1887 by Dr. A. Winchell. Later Mr. Warren Upham made some examination of the drift in 1893, and Mr. A. D. Meeds did the topographic work on which the contours are drawn throughout the southern and central portions of the area. Mr. J. E. Spurr specially examined and reported on that portion of the Mesabi range in which are located the principal recent developments. These, with special visits and re-examinations by the writer at important points in 1888 and 1889, and also in 1896 and 1898, constitute the basis on which this report is founded.

The earlier examinations by Chas. Whittlesey, and by H. H. Eames, should also be mentioned, the former being the earliest geologist to leave a record of his observations in this region, and the latter the discoverer of the iron ores of the Vermilion range in 1866.



I T A S C A
C O
T.55N.
T.56N.
T.57N.
T.58N.
T.59N.
T.60N.
T.61N.
T.62N.
R.XXIV W.
R.XXW.
R.XIXW.
R.XVIIIW.
R.XVIIW.
R.XVIW.
R.XV W.
R.XIVW.
R.XIIIW.
R.XIIW.
HIBBING
DULUTH MISSISSIPPI RIVER & NORTHERN R.R.
SUPERIOR BRANCH
D. M. AND N. R. R.
SHAW
WOLF
Seventh Correction Line
Eighth Correction Line
Sandy Lake
Pike River
EMBARRASS RIVER
NORWAY
TOWER
MESABA
ST. LOUIS RIVER
DASSETT LAKE
CLOQUET RIV.
West Branch Cloquet R.
Stone Lake
Seven Beaver Lake
Dunka River
L A K E
C O U N

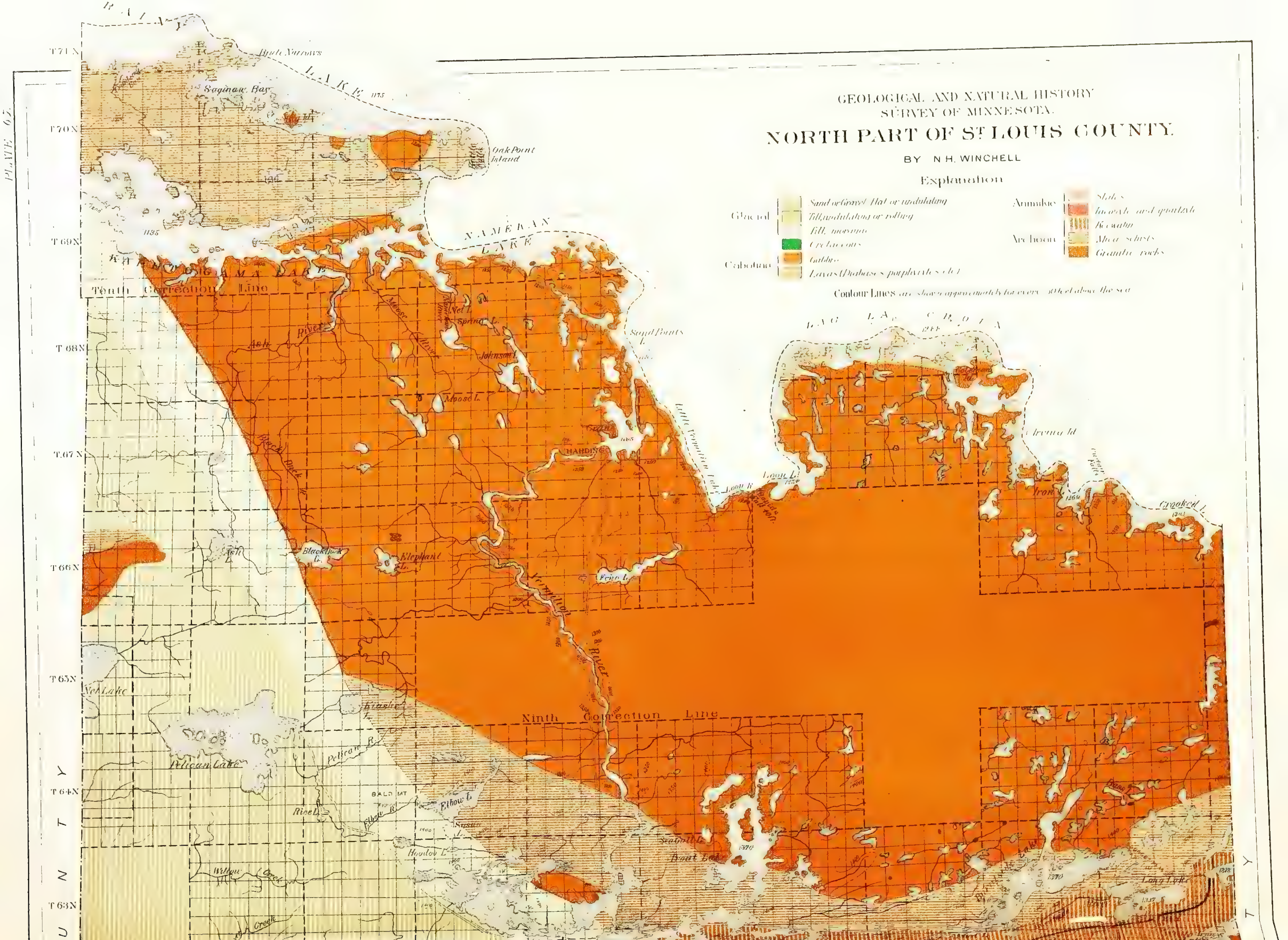

GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.
NORTH PART OF ST. LOUIS COUNTY.
BY N. H. WINCHELL
Explanation
Glacial
Sand or Gravel Flat or undulating
Till, undulating or rolling
Till, morainic
Cretaceous
Cabotian
Gabbro
Lavas (Diabases porphyrites etc.)
Animikie
Slates
Archean
Keewatin
Mica schists
Granitic rocks
Contour Lines are shown approximately for every 50 feet above the sea
Tenth Correction Line
Ninth Correction Line
T 71 N
T 70 N
T 69 N
T 68 N
T 67 N
T 66 N
T 65 N
T 64 N
T 63 N
Saginaw Bay
Oak Point Island
NAMEKAN LAKE
Sand Point L.
Little Vermilion Lake
Loon L.
Crooked L.
Vermilion River
Ash River
Black Duck L.
Elephant L.
Pelican Lake
Pelican R.
Net Lake
Johnson L.
Moose L.
Trout Lake
Long Lake
Elbow L.
HARDING
BALD MT.

FIG. 1. MESABI SUMMIT SWAMP, MUSKEG CROSSED BY THE DULUTH & IRON RANGE R. R., T. 56-14. (p. 223.)

FIG. 2. VIEW ACROSS LONG LAKE, LOOKING SOUTHEAST. ELY IN THE DISTANCE. (p. 226.)

T. 55–14. Surface is generally flat or moderately undulating.

T. 55–15. Crossed from northeast to southwest by the White Face river. The town is well drained, in general, but not uneven.

T. 55–16. The eastern half is slightly undulating or rolling, underlain by till, but the western is flat and occupied to some extent with muskeg, underlain by fine sand or gravel.

T. 55–17. Principally occupied by muskeg, underlain by washed drift. Dry land extends through sections 6, 5, 4, 3, 10, 11 to 13 and 24.

T. 55–18. Mostly muskeg.

T. 55–19. Mainly muskeg, the better drained strips along the streams supporting a considerable growth of timber. Underlain by finely washed drift.

T. 55–20. Flat, mainly muskeg, underlain everywhere by stratified sands and gravels.

T. 55–21. Nearly level, on the whole, but undulating with variations of ten to forty feet. The eastern and southern two-thirds are covered by muskeg, but the northwestern is dry. The town is underlain by stratified sand and gravel, becoming coarse toward the north.

T. 56–12. This town is crossed by a series of valleys and low divides running northeast and southwest wholly within the drift-sheet. No rock is known except boulders. The whole town is characterized by low undulations, with detached swampy tracts.

T. 56–13. Very similar to the last, but more flat toward the north. Numerous gabbro boulders are seen.

T. 56–14. Very similar to the last. With the gabbro boulders are some of granite, quartzyte and Animikie.

T. 56–15. Very similar to the last, but the low land is not so uniformly in the form of swamps extending northeast and southwest. The northwestern corner, including sections 18, 7, 5 and 6, are flat and underlain by fine washed sand and gravel.

T. 56–16. The till surface extends over about one-fourth of this town, in the southeast, and the rest of the town is flat and considerably covered by muskeg. The scattered dry ridges are somewhat timbered.

T. 56–17. Largely muskeg, but with patches a few feet higher than the general level, which support a growth of timber, largely of pine.

T. 56–18. Level, stratified drift, with much muskeg in the eastern part.

T. 56–19. Mainly muskeg.

T. 56–20. Flat, mainly muskeg, underlain by sands and coarser washed drift. In the northwest corner, including sections 18, 7, 6, and portions of 8 and 5, the surface is of till.

T. 56–21. This town is also generally about flat, but becomes undulating in sections 3 and 4. The most of it is underlain by till, but stratified sands cover the till in the southern sections.

T. 57–12. The valleys, which run northeast and southwest, are separated by low ridges composed outwardly of drift, but probably based on gabbro, of which many boulders are scattered over the surface, and about the water courses.

T. 57 13. This town is similar to the last. Grandmother hill, composed of gabbro, situated on the line between sections 8 and 17, rises abruptly about 250 feet above the general surface. Much of this town is wet, with cedar and tamarack swamps.

T. 57–14. Generally dry, but flat.

T. 57–15. Generally flat, with some swamps, especially in the northwest.

T. 57–16. Level, washed drift, better drained along the Embarras and St. Louis rivers. Swamp in sections 5, 6, 7 and 18, and smaller swamps scattered.

T. 57–17. This town is generally level, and underlain by washed drift. A rolling till surface, however, is found in sections 6, 5 and 4, where the land rises rather abruptly to 300 feet above Cedar Island lake. The town is swampy where flat, but not entirely of muskeg.

T. 57–18. This town is very similar to the last, but has more dry land. It is in general underlain by level sands and gravels. An elevated till-covered surface is found in section 1.

T. 57–19. Generally flat, although till underlies the northwestern one-third. Much muskeg and other swampy surface.

T. 57–20. A belt of dry land enters this town from the south, about a mile wide, along the stream in section 34. This runs northward to section 10, turning east to include sections 11, 12 and 14, and 13. In section 28 it also branches westward, including parts of sections 20, 29, and widens north and south from Hibbing to the southern side of the town. The rest of the town is low and often swampy. About Hibbing the till exhibits morainic characters.

T. 57–21. This town, wholly underlain by till, has a rolling or undulating surface, which in the northern tier of sections, and in sections 7 and 8, becomes morainic. There is more or less swamp, but not muskeg.

T. 58–12. In general the surface is of till and rather flat, with marshes. Numerous gabbro boulders and a few of granite are scattered about the lake shores and elsewhere. These boulders sometimes are in bunches or low ridges, in the swamps and about the lakes.

T. 58–13. Similar to the last, probably underlain by grabbro (under till), on which is frequently much wet land. Ridges of gabbro boulders are conspicuous in sections 17 and 18. The extensive muskegs, of this region crossed by the Duluth and Iron Range railroad are represented by plate R, figure 1.

T. 58–14. Ridges of gabbro, of irregular shape, occur from Allen Junction to Allen and eastward, overstrewn with many boulders, sometimes in low, loose ridges. The drift is of till, except when washed and

deposited as gravel and sand, and much of it is low and swampy. The northern two tiers of sections are frequently rolling, and especially about Partridge and Sunfish lakes.

T. 58–15. This town is mainly dry, with an undulating till surface—rolling in the north. The till is frequently replaced, in the southern and central areas, by glacial gravels which have a rather flat-upper contour.

T. 58–16. This town is considerably diversified, with elevations ranging from 1,400 to 1,700 feet above the sea; Esquagama lake being still lower, or 1,353 feet. The elevated ridge of granite, in sections 5 and 7, has its culmination in N. E. ¼ sec. 7. The region is covered with till, which also extends eastward to Biwabik and Merritt. Southward from McKinley and Merritt the surface is composed of modified drift (chiefly gravel and sand), which, being flat, is still mostly dry.

T. 58-17. This town is rough, not only by reason of the underlying rock, but by reason of the posé of the drift, which is everywhere till, except in sections 25, 35 and 36. There are three points that reach an elevation of nearly 2,000 feet, viz.: N. W. ¼ S. W. ¼ sec. 21, 1,927 feet; S. W. ¼ S. W. ¼ sec. 28, 1,950 feet, and S. E. ¼ S. E. ¼ sec. 28, 1,990 feet. At Virginia and southwestward is an area of flat and wet land, based on the till, with some overlying compact clay.

T. 58–18. This town varies in altitude from about 1,400 feet in the southwest corner to about 1,700 in the northwest corner. It is principally occupied by till, which is morainic along the northern tier of sections, but the central southern area is flat and covered by washed drift, with a large area of swamp.

T. 58–19. The northern part of this town is about 350 feet higher than the southern, due to the underlying formations, but the whole town has a covering of till, which is morainic in the north, but undulating or flat in the southern.

T. 58–20. A morainic belt about a mile and a half or two miles wide crosses this town, from section 30 to section 12. Throughout this the surface is abundantly strewn, and sometimes almost covered, by boulders mainly of granite. The rest of the till is apt to be fine blue clay, though often stained red for several feet at the surface, and containing sparingly small boulders and fragments. Through all are occasional patches of washed gravels. Aside from this morainic belt, the drift is flat or undulating, and the drainage is to the north and to the south, with much swamp toward the north.

T. 58–21. The morainic belt last mentioned covers, in this town, the lowest two tiers of sections at first, but its northern edge falls away in sections 28 and 29, and leaves the town at the point where the stream enters it in section 31. Toward the north is an undulating drift-covered country with scattered small swamps.

T. 59–12. Mostly dry and level, highest in the southeast. Till or gravelly till.

T. 59–13. Till, but mostly wet. Dry and elevated in N. W. ¼ sec. 6. Probably underlain by gabbro.

T. 59–14. The hights of the Giant's range are 1,850 feet, and occasionally 1,900 feet, above the sea. From this the surface descends to 1,500 feet, and less, toward the northwest and toward the south. The drift is generally stony till, and through the central portions short sharp ridges of boulders of granite and of gabbro are common. Some swampy land, not muskeg, is found in the southern half of the town.

T. 59–15. The granite of the Giant's range crosses this town, rising to 1,900 feet in section 13, and to 1,850 in section 20. Sabin lake is at an elevation of 1,380 feet. South of the Giant's range the country is dry, but it is swampy north of it. The Embarras river runs through an area of muskeg, which extends nearly to Sabin lake. A moraine crosses the town, Sabin lake being in a valley of north and south glacial drainage kept open through the moraine. On either side of this lake the drift hills rise from 250 to 300 feet above the lake, viz.: in sections 29 and 30.

T. 59–16. The hill range covering sections 26 and 35 rises to over 1,750 feet above the sea, consisting of granite principally, buried under morainic drift. Pike river valley is another old drainage course kept open during the glacial accumulations. The moraine on the west side of this old valley rises to 1,900 feet in the N. W. ¼ sec. 31. The highest land here is crossed by the town line. Aside from the swampy land that accompanies the Pike river this town is generally dry. Along the immediate valley is considerable modified drift, northward from the moraine. The general level of the town is about 1,500 feet.

T. 59–17. The high hill in section 28, composed of granite, obscured by till, rises to over 2,150 feet, and that in section 26 to 2,025 feet, the former being the highest point within the area represented by this plate. The town is in general occupied by till, which is morainic in the southern half.

T. 59–18. The southern one-third portion of this town is morainic, and the remainder has a considerable swamp. Westward from Sandy lake is a belt about a mile wide, which is occupied by a superficial stratum of coarse modified drift, which has a more or less rolling topography. The highest land is in north part of section 26, rising to 1,860 feet.

T. 59–19. The spur of the Giant's range crossing sections 35 and 36 rises to 1,820 feet. Morainic till is on it and extends about a mile north of it, and westward into section 32. A little more than one-half of the town is covered with gravel or gravelly till, with an undulating outline, its southern border running from the south side of section 20 east-northeast to the northeast corner of section 13. Between this area and the morainic surface is a belt a mile to a mile and a half in width which is occupied by ordinary undulating till.

T. 59–20. Mainly a gravelly and till surface, dry, sloping north; mostly flat, but more rolling in section 36.

T. 59–21. Mainly flat and gravelly, with some swamps in the northwest.

T. 60–12. An undulating or rolling till surface, with gravelly patches and small swampy tracts. The various branches of the Dunka river give it good drainage, and by their erosion a more broken surface. Some prominent hills of granite belonging to the Giant's range are found in sections 7, 8 and 9. Low gabbro ridges

prevail in the eastern half of the town. There is a heavy drift, probably of the nature of a moraine, running across the northern part of this town, the most northern of the later moraines of the lake Superior ice-lobe.

T. 60–13. The narrow granite ridge of the Giant's range, which crosses this town from southwest to northeast, rises to the hight of about 1,800 feet, its highest point being 1,865 feet, north side of section 23. The rocks of the Mesabi iron range form lower hills along the south side, and gradually slope to the low land drained into the Partridge river. Toward the north the descent is more abrupt to the valley of the upper Embarras river, which flows through a region of swamp, and which rises in a small lake in section 3. The northeastern portion of this town is heavily drift-covered, charactistic of the region about the western and southern sides of Birch lake, and probably marks a marginal moraine belt of the lake Superior ice-lobe. The Giant's range begins to sink away in sections 14, 13, and 12, and is wholly lost, as a hill range, in the next town east.

T. 60–14. This town is considerably broken and rolling, with many swamps in the depressions, drained slowly by the Embarras river. The drift effectually covers the rocks. The surface rises about 250 feet in southeast part of section 36, caused by approach to the Giant's range.

T. 60–15. The general character of this town is like that of the last.

T. 60–16. This town is heavily drifted, but the immediate surface is of permeable materials, making it generally dry. The uplands are of glacial gravels or of till, and the valley of Pike river is in washed sands and gravels of post-glacial date as to present posé, though probably originally of glacial origin. In the northwest corner, sections 18 and 7, glacial gravels form a rolling surface.

T. 60–17. There is some till in the southern part of this town, in a belt about a mile and a half wide, but on the southern side (sections 35 and 36) it is limited by river-washed gravels, and toward the north, occupying the rest of the town, are glacial gravels forming an undulating or rolling surface, with much swamp.

T. 60–18. This town is almost entirely occupied by glacial gravels, and has a rough contour, some of the hills rising 150 feet above the valleys. Yet in the northeastern corner are about four sections covered by marsh, which lies on both sides of the stream which flows from Rice lake.

T. 60–19. There is a little swampy land along the stream which flows westward in the northern part of this town, but it is otherwise dry and gravel-covered, with rather broken surface.

T. 60–20. This town is probably occupied by glacial gravels, in a manner similar to the last, but it has not been examined. The surface is level or gently rolling, according to the United States surveyor.

T. 60–21. Similar to the last, but with a large swampy tract in the northeast.

T. 61–12. The contour of this town is rather diversified. The irregularities of the rocky surface have been generally toned down and sometimes entirely hid by the drift deposits, which are copious, and which have superimposed their own topography. There is evidence of a glacial lake having covered the most of the town, at least the southern portion of it, while the eastern end of Birch lake was obstructed by the glacier. A terraced condition of the drift deposits is noticeable along the south side of Birch lake (more visible in Ts. 60 12 and 61–11), the drift being characterized by abundance of debris, which must have originated further south.

T. 61–13. This town is similar to the last. The outlet of the glacial lake mentioned above must have been through section 23, into Stuntz lake and thence northeastward to White Iron lake. In case the northern ice and the lake Superior ice-lobe co-existed at about this locality, the former then accumulating the Vermilion moraine, the outlet of this glacial lake must have been toward the southwest by way of the valley of the Embarras river.

T. 61–14. This town has not been examined, but it is probably covered by glacial gravels with rolling contours. The lakes in the northern part are deep, with rocky shores.

T. 61–15. This town is also heavily drift-covered, with occasional rocky knobs rising above the general surface, especially in the northwest.

T. 61–16. Generally dry and rolling, gravelly, with rocky knobs. A great many boulders are strewn over the surface, especially in the northern part.

T. 61–17. Surface rolling, gravelly, frequently wet, with spruce and tamarack swamps.

T. 61–18. Surface rolling, with spruce and tamarack swamps. Drift generally gravel.

T. 61–19. Similar to the last, but rocky in the northeast.

T. 61–20. Level or undulating, probably gravelly. Uplands timbered with aspen, spruce and balsam fir, with scattering pine. Swamps with spruce and tamarack.

T. 61–21. Level or undulating, generally of glacial gravels.

T. 62–12. Surface is rolling, with hills of rock and of drift. Large deposits of terraced gravel, etc., occur about White Iron lake, especially in sections 23 and 26.

T. 62–13. Surface much broken and the rock frequently exposed, glaciated southwest-west. Generally dry, but with occasional swamps of spruce and tamarack.

T. 62–14. Characterized by rock ridges extending in general east and west. Country generally dry. Ridges from 50 to 100 feet, or 150 feet, above the valleys. Much rock exposure.

T. 62–15. About the shores of Vermilion lake is abundant rock exposure, the lake being at an altitude of 1,357 feet. But the southwest shores are drifted throughout its whole length, with only rare rock exposures. A morainic belt is supposed to cross this town through the southern sections, named by Mr. Upham the Vermilion moraine. The rock ridges from which iron is mined in sections 27 and 33, rise from 200 to 300 feet above Vermilion lake.

T. 62–16. A range of morainic till skirts the southwest side of Vermilion lake (the Vermilion moraine). The rocks are but rarely exposed about the southerly shores in this town. Southwest from this belt the country is low and wet.

T. 62–17. Similar to the last.

T. 63–12. The general and much of the detailed topography of this town is due to the form of the underlying rock-surface, but there is also a large deposit of drift. There are terraced gravels south of Long lake west from Ely and bordering its north shore, as well as stoneless clays about the east end of the same lake. An elevated ridge, largely composed of rock, runs through sections 33, 34, 35, and 36, and another along the north side of Long lake. Indeed, the whole town is marked by a succession of east-west ridges wrought in the rock, these ridges rising from 50 to 150 feet, and more, above the valleys (plate R, figure 2).

T. 63–13. This town is similar to the last, but the lower portion of the valley of the Burntside river was covered by the glacial lake that occupied the valley of Long lake, and it is now covered by fine clay, extending nearly to the outlet of Burntside lake. The rocky areas also are not distinctly east-west ridges, but irregular knolls and hills. These prevail throughout Burntside lake and northward, with scant drift. A hill range runs through sections 33, 34, 35, and 25.

T. 63–14. This town is rough, with frequent hills of granite, not having an abundant drift. The lakes are rock-bound.

T. 63–15. Rough, with the rocky structure (granite). In the southern portion some tracts more level, but still rocky.

T. 63–16. Granite and schists make this a rough town, the drift not being thick.

T. 63–17. Generally quite rocky and rough, but frequently wet, with more drift and uniform characters in the southwest, where boulders form the lake shores.

T. 63–18. Abundant drift covers the southwestern one-third or one-half of this town where the lake shores are of boulders. But toward the northeast the rock is more uncovered, and the country is more broken.

T. 63–19. This town is heavily drifted, with no known rock outcrops. The Vermilion moraine passes through the northeastern portion. Marginal moraine gravel deposits, with a rolling or undulating surface, are supposed to occur in the south. The town, however, has not been examined.

T. 63–20. This town has not been examined, but is probably quite similar to the last.

T. 64–12. This town is unexamined, but it is known from general considerations to be generally rough, with ridges and knobs of granite and gneiss, with rock-bound deep lakes.

T. 64–13. Similar to last.

T. 64–15. Rough, with hills and ridges of gneiss and granite, varying to mica schist.

T. 64–16. Rough, with much rocky surface, with interspersed swamps; smoother in the north.

T. 64–17. The river is wide and slow, occasionally with granite shores, but generally having drift shores. The country rises gently on either hand, but for the most part not exceeding twenty-five feet near the river; occasionally higher land appears at a distance, but the town, although underlain by granite rocks, is not very hilly.

At the outlet of Vermilion lake, the water-surface goes down about fifty feet to a lower lake, with considerable tumult, over large boulders of coarse granite, without much exposing the underlying rock *in situ* along the river. The underlying rock is rather fragile mica schist, visible on the east side of the bay from which the river goes out, and represented by fresh slabs of that kind of rock scattered about the outlet (plate S, figures 1 and 2).

T. 64–18. This town is moderately rough, with hills of gneiss and of granite, interspersed with small swamps.

T. 64–19. Elbow river runs through a very rough country in sections 24, 25, 26 and 34, the hills rising about 200 feet above the river, Bald mountain being on the north side. The rapids are at the outlet of Elbow lake and at a distance of two and a half or three miles below. The outlook from Bald mountain is over a forbidding country of hornblendic and chloritic gneiss. The stream is remarkably free from rapids for so rough a country. Through sections 33, 29 and 19, the immediate valley is swampy and contains Rice lake.

T. 64–20. The shores of Pelican lake are not very high, nor rocky, but mostly sandy or boulder-bound. There are reported considerable drift hills in central and southern portions of this town, the supposed location of the Vermilion moraine (Upham). The underlying rocks are granite, gneiss and mica schist.

T. 64–21. The Vermilion moraine probably passes through this town (Upham), but the interior of the town has not been examined. There is more reason to believe, however, that the Vermilion moraine lies to the east of Pelican lake.

T. 65–17. The Vermilion river passes through the centre of this town, which has not been subdivided. It has an extensive rapid over granite in section 35, with a fall of about eighty feet. There is another rapid about in section 27, with fall of about six inches. There is a fall of fifteen feet near the centre of section 22, over gneiss, and another in the southern part of section 9, of six feet, over gneiss. In general, this stream, however, is rather steady, in this town, with drift banks, the country being flat except at the points mentioned, where hills appear on either side. The stream is in contrast with the drainage courses farther east and north, which are composed rather of a succession of lakes. This flat country continues to Crane lake.

T. 65–19. Not examined.

T. 65–21. In only two places near Net lake is rock *in situ* known. This is on a small island, near the east side of the lake, just west of the Indian village. Mica schist also crops out in the midst of the Indian village. The portage from Pelican to Net lake is over a region of drift, with much gravel and sand, and many large boulders. The Vermilion moraine probably runs to the east of Net lake, and from it a gravel-covered and finally a silted surface spreads out toward the west and southwest, incidental to the waters of lake Agassiz.

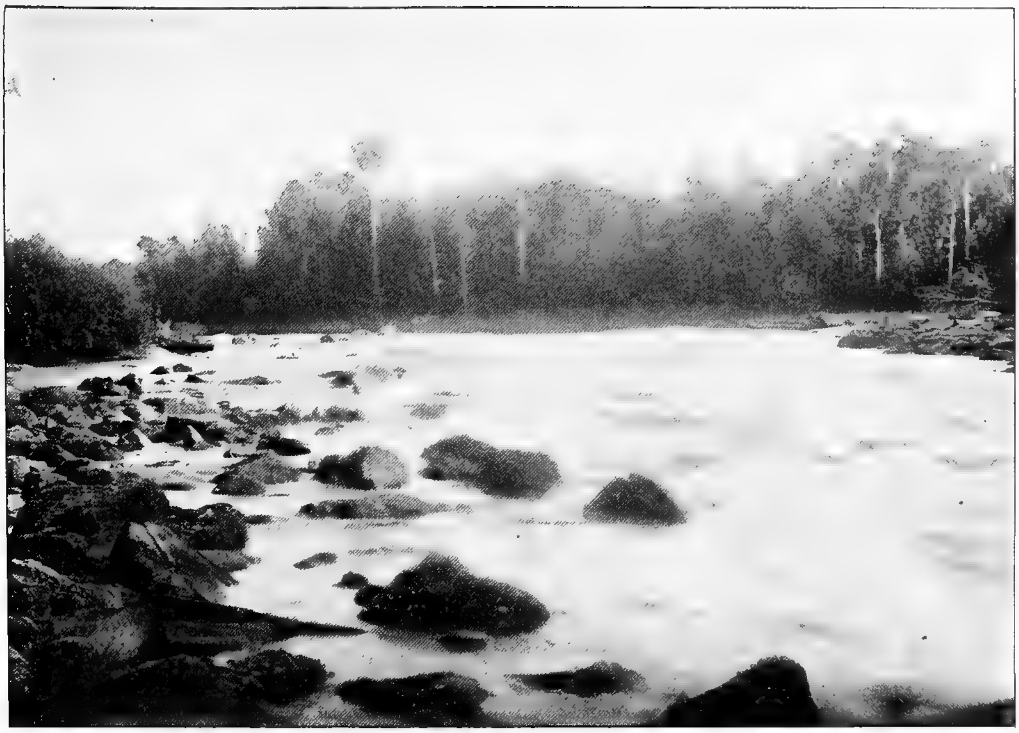


FIG. 1. OUTLET OF VERMILION LAKE, LOOKING SOUTH OVER MICA SCHIST. (pp. 226 and 242.)

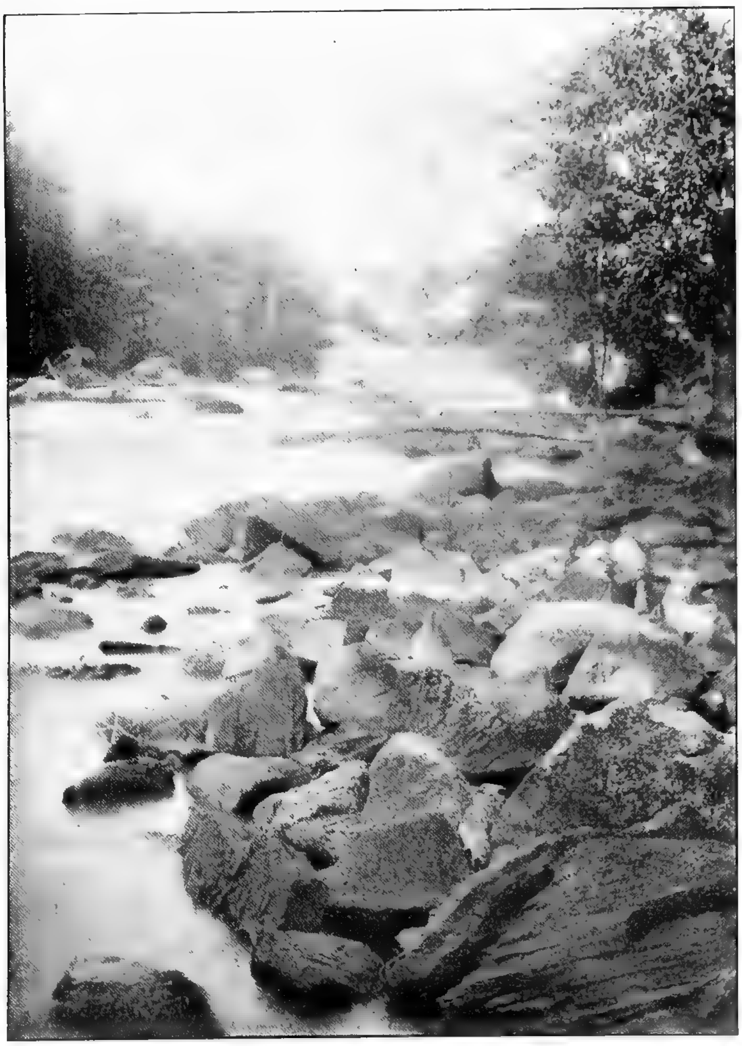


FIG. 2. LOOKING FROM THE OUTLET OF VERMILION LAKE NORTHWARD, INCLUDING A PORTION OF A LOWER LAKE. (pp. 226 and 242.)

FIG. 1. CURTAIN FALLS, OUTLET OF CROOKED LAKE, SEC. 6, T. 66-12. (pp. 227 and 243.)

FIG. 2. GORGE AND FALLS IN THE VERMILION RIVER, N. E. ¼ SEC. 30, T. 67-17, CUT IN GNEISS. (pp. 227 and 242.)

T. 66–12. This town borders on Crooked lake, which is a part of the waters of the international boundary. The country is rather broken, underlain by the gneiss and schists of the Archean. At the outlet of Crooked lake is Curtain fall (plate T, figure 1), where the water descends 27 feet. Below the fall is a rapid in which the water descends again about three feet, thus reaching Iron lake.

T. 66–13. The surface of this town is much broken, having high hills and precipitous ledges of granitic rocks.

T. 66–14 and 15 have not been subdivided. They are probably quite hilly, with granitic rocks.

T. 66–16. Loon river, crossing sections 1, 2 and 3, is a sinuous stream. The shores are low, rising five to twenty-five feet, but in places having higher land not far to the south. The rapid which occurs at the northeast corner of section 1 affords a fall of about forty feet, that at half a mile further west has a descent of about four feet, and that on the section line between sections 1 and 2, about six inches. Otherwise the stream is smooth in this town.

T. 66–17. This town is occupied by hills of granite. The Vermilion river, however, is steady and receives the Pelican in N. W. ¼ sec. 31.

T. 66–18. The Vermilion has a steady descent through this town, which, however, is broken by a rapid and fall of nine feet near the centre of section 24. There is also a small rapid and descent of one foot about on the section line between 10 and 15 in the N. E. ¼ sec. 15. The immediate banks of the river are generally not rocky, but hills of granite rise at a short distance on either hand, and the town is generally rough.

T. 66–19. Not examined.

T. 66–20. Not examined, but it is known that a very hilly tract, probably of drift, occurs to the west and southwest of Black Duck lake, the assumed location of the Vermilion moraine.

T. 66–21. Not examined, but this town is probably occupied by a flat or undulating drift, which consists largely of gravel and sand, rendering the surface dry, with only occasionally low knolls of rock.

T. 67–13. This is hilly, with gneiss and granite and mica schists. The international boundary waters on leaving Iron lake pass to the east and north of Irving island, but the boundary line, as laid out and recognized by the United States surveyors, turns to the west in the N. W. ¼ sec. 35, where water goes only at high stage. It thus reaches Lac la Croix by the stream in section 34. The main boundary stream goes north from Iron lake to McAree lake, and thence to Lac la Croix. The boundary line follows the dry channel from Iron lake and enters a small lake in S. W. ¼ sec. 26, leaves it, and continues northwestwardly over a tongue of land projecting southwest from Irving island, and descends to Lac la Croix, in the S. E. ¼ of sec. 27. In the portage across Irving island the United States section lines are meandered up to the portage trail.

T. 67–14. Lac la Croix has a spider-like extension over the eastern and northern parts of this town. Otherwise it is rough or hilly, with the Archean rocks.

T. 67–15. The shores are rocky and sparsely timbered. The country is hilly. Only in very high water is there any current passing from Lac la Croix southward to Loon lake, where the international boundary is located, although there is a descent of twenty feet to Loon lake.

T. 67–16. Little Vermilion lake, which receives Loon river, extends from section 28 to section 6, crossing this town. This stretch of water, which is narrow and river-like nearly all the way, is sometimes very sinuous, with low, grassy, marshy banks. Just at the point where it leaves the town, N. W. ¼ sec. 6, is a rapid with descent of about a foot. The country in general is hilly and rocky, with scant forest.

T. 67–17. The Vermilion river has a fall of twenty-one feet, through rapids, on N. E. ¼ sec. 30 (plate T, figure 2), and another of six and a half feet at the section corner 19-20, 29-30, over gneiss at both places. There is another rapid over mica schist and granite, with a descent of eight inches, in N. E. ¼ sec. 20. The portage that descends eastward from S. E. ¼ sec. 21, to the N. W. ¼ sec. 22, has a fall of forty-five feet, the rapids continuing for more than half a mile. From this the water has but a very gentle descent to Crane lake, which spreads irregularly over the northern and eastern parts of this town and into the town next east. This town is generally rather broken with granitic hills.

T. 67 18. This town has not been examined except along the Vermilion river, where it is broken with granitic hills. It is believed to be generally of the same character.

T. 67-19. Not examined, but the town is probably rough, with numerous granitic hills.

T. 67-20. Not examined, but it is probable that the line separating the rocky country from the drift-covered passes through this town. It is the same transition that is so noticeable at the west end of Rainy lake and along the southwest side of Vermilion lake.

T. 67–21. Not examined, but this town is supposed to be flat or undulating, with a considerable drift-mantle, consisting largely of gravel and sand.

T. 68–13. The land of this town is a part of an island in Lac la Croix, which the Canadian maps name Roland, but which by Minnesota maps is named Coleman island. The surface is nearly level, but yet rocky.

T. 68–14. This town, lying on Lac la Croix, is rough and hilly, with Archean rocks, but is well timbered.

T. 68–15. Similar to the last, with bold rocky shores.

T. 68-16. The small patch of land belonging to this town (in section 31) is hilly but well timbered. It is on the point of the peninsula between Crane lake and Little Vermilion lake.

T. 68–17. At the narrow place separating Crane lake from Sand Points lake there is a little current and a descent northward of three or four inches. This narrow place is in the southern part of section 36. Sand Points lake spreads irregularly over the most of this town, which is otherwise rather rough, with Archean rocks.

T. 68–18. Rough, with Archean hills.

T. 68–19. In the lower reaches is found occasional swamp, but generally this town is hilly, with little or no drift covering the rock.

T. 68–20. Not examined, but it is learned from the United States township plats that a considerable swampy land lies along the water courses. The town is probably considerably drift-covered, the eastern edge of the Vermilion moraine lying in the southwestern part.

T. 68–21. Not examined, but supposed to be well drifted, and rather flat, with modified drift abundant—the Vermilion moraine probably affecting the northeastern portion.

T. 69–17. Hilly and rocky. At the outlet of Sand Points lake into Namekan lake there is a distinct current, and a descent of not more than six inches. This occurs near the centre of section 27.

T. 69–18. This town is rough, with granitic hills.

T. 69–19. The assumed limit of Namekan lake, westward, is at the narrows in section 29, but the lakes are on the same level. The surface of this town is similar to that of the last.

T. 69–20. Surface broken, with Archean rocks frequently exposed. Kabetogama lake extends east and west across this town. More drifted in the southwest.

T. 69–21. This town is similar to the last, but is more largely covered by Kabetogama lake. The rock is bare abundantly about the lake shores. The Vermilion moraine is presumed to cross the southwestern quarter of this town, separating the rocky land from that which is drift-covered, but the town has not been examined except along the lake shore.

T. 70–18. The Namekan lake empties into Rainy lake at Kettle falls, with a descent of about eight feet. These falls are at the southeast corner of section 33. The town is hilly, with granite and mica schist.

T. 70–19. Similar to the last.

T. 70–20. Rocky, gently rolling; rock, mica schist; shores lower than further east, and tending to be marshy.

T. 70–21. Similar to the last.

T. 71–20. Hilly. The point projecting to Brulé narrows is generally low. The rock is generally of mica schist.

T. 71–21. Surface rolling and rocky, with mica schist. Numerous islands are near the shore.

ELEVATIONS IN THE NORTHERN PART OF ST. LOUIS COUNTY.

Duluth and Iron Range railroad.

	Miles from Duluth.	Feet above tide.
Highland (formerly Gakadina),	38.6	1,709
Summit (highest point on the line, cut 4 feet), grade,	39.5	1,744
Thomas,	43.3	1,610
Little Cloquet river, bed, 1,489; grade,	45.2	1,521
Cloquet river, bed, 1,477; grade,	47.2	1,493
Cloquet River station,	47.7	1,505
Breda (formerly Wissakode)	50.8	1,580
Summit, grade and natural surface,	52.6	1.622
Outlet of Basset lake, bed, 1,575; grade,	54.2	1,594
Basset Lake station,	54.8	1,638
White Face river, bed, 1,606; grade,	56.4	1,635
Summit, cutting 14 feet; grade,	58.8	1,695
Reno,	60.5	1,665
St. Louis river, bed, 1,583; grade,	63.1	1,597
St. Louis River station,	64.0	1,584
Summit, cutting 10 feet; grade,	64.8	1,609
Partridge river, bed, 1,489; grade,	69.3	1,504
Allen Junction,	70.0	1,508
Beaver Dam creek, bed, 1,472; grade,	71.2	1,484
Allen (formerly Okwanim),	71.4	1,481
Junction of survey to Mallmann mine,	72.9	1,527
Camp at Mallmann mine (N. E. cor. sec. 11, T. 59–14),	77.3	1,685
Summ't, cut 7 feet; grade,	73.2	1,529
Mesabi,	74.0	1,512
Mesabi creek, bed, 1,481; grade,	74.7	1,488
Hinsdale, at Summit, cut 10 feet; grade,	76.3	1,596
Embarras river, bed 1,408; grade,	80.9	1,426
Embarras River station,	81.8	1,426
Norway,	84.1	1,472
Summit, natural surface and grade,	84.7	1,487
West Two rivers at first bridge, bed, 1,432; grade,	89.2	1,438
West Two rivers at sixth bridge (?), bed, 1,403; grade,	90.7	1,414
West Two Rivers station,	91.1	1,425
Summit, natural surface and grade,	91.4	1,441

	Miles from Duluth.	Feet above tide.
East Two rivers, bed, 1,375; grade,	92.8	1,385
Tower Junction,	93.0	1,381
East Two rivers, grade,	93.5	1.381
Tower,	94.4	1,367
Vermilion lake, water,	95.2	1,357
Summit of grade (branch to the mines),	94.6	1,510
End of track at Stantz mine,	94.9	1,491
Summit, grade and natural surface (branch to Ely),	100.1	1,516
Armstrong Lake station (side track),	102.8	1,476
Robinson Lake siding,	104.2	1,482
Depression, grade,	110.1	1,377
[This is at the foot of a descent from the west; forward the grade is nowhere above 1,386 feet to 112 miles.]		
Ely,	113.4	1,417
Garden lake, water,	120.0	1,384
Kawishiwi river, water,	120.2	1,383

Duluth and Iron Range railroad—Western Mesabi branch.

	Miles from Duluth.	Feet above tide.
Allen Junction,	70.0	1,508
Mesabi creek, bed, 1,430; water, 1,432; grade,	75.7	1,440
Summit, cut 2 feet; grade,	77.0	1,478
Embarras river, bed, 1,363; water, 1,366; grade,	82.5	1,380
[The river here has the same level as the Upper Embarras lake (1,366 feet) next north; rapids fall 5 or 6 feet just below this bridge to the Lower Embarras lake (about 1,360 feet).]		
Junction of branch to mines,	84.0	1,425
Junction of branch to the Cincinnati mine,	84.0	1,432
End of track (Cincinnati mine),	85.5	1,568
On the branch to the Canton mine, crossing of the Biwabik branch of the Duluth, Mesabi and Northern railroad; grade,	85.0	1,456
Canton mine, west and upper shaft; surface,	85.2	1,492
McKinley town-site,	87.4–87.7	1,432–1,440
Summit, cut 26 feet; grade,	90.6	1,589
Pike river, water, 1,532; grade (on trestle, 46 feet high),	91.0	1,578
Rock, cut 500 feet long, natural surface, 1,605; grade,	91.2	1,573
Deep, cut in drift, 1,200 feet long, natural surface, 1,646; grade,	92.5	1,608
Crossing (above) Duluth, Mesabi and Northern railroad (1,563); grade,	92.8	1,598
[From 94.0 to 97.0 miles this road makes a long and narrow loop, convex to the northeast, in descending across the valley of Six Mile creek, which runs west into a small lake close north of Virginia. This loop is mostly in the southern two-thirds of sec. 4, T. 58–17.]		
Small stream, from springs, bed, 1,425; grade,	97.6	1,434
Lake at Virginia,		1,423
General level at Virginia, one-half mile south of this railroad,	97.6	1,435 1,440
Summit, cutting 17 feet; grade,	100.0	1,463
Crossing (above) Duluth, Mesabi and Northern railroad (1,433); grade,	101.9	1,463
Junction of two lines of survey westward,	103.3	1,542
On the southern line.		
Summit, cut 2 feet; grade,	103.4	1,545
Stream, bed, 1,501; grade,	104.1	1,538
On the northern line.		
Cedar swamp, forming the divide between the St. Louis and Rainy Lake river basins, N. W. ¼, sec. 6, T. 58–18; surface,	105.0	1,615
[This profile ends on the west line of this range 223 feet north of the ¼ section stake on the west side of sec. 30, T. 59–18, natural surface, 1549–1578.]		
Proposed grade at end of survey,	106.9	1,559

Duluth, Mesabi and Northern railroad.

	Miles from Duluth.	Feet above tide.
White Face river, water, 1,281; grade,	60.1	1,302
[From Albert northward to the second crossing of the St. Louis river this country consists mainly of tamarack swamps and muskeg.]		
Summit, in a grove of Norway pine, natural surface and grade,	72.5	1,355

	Miles from Duluth.	Feet above tide.
St. Louis river (second crossing), bed, 1,296; water, 1,300; grade,	74.8	1,335
Shaw,	74.9	1,339
Summit, cutting 13 feet; grade,	77.1	1,358
Creek, bed, 1,343,	77.7	1,351
Creek, bed, 1,345,	78.1	1,358
Iron Junction of Biwabik branch,	78.8	1,379
Summit, cutting 2 feet; grade,	79.3	1,392
Creek, bed, 1,367; grade,	79.6	1,387
Creek, bed, 1,362; grade,	80.0	1,389
Ore Junction of Mesabi Mountain branch,	81.1	1,402
Summit, natural surface and grade,	83.8	1,413
Depression and culvert, bed, 1,392; grade,	84.9	1,397
Creek, bed, 1,396; grade,	86.1	1,402
End of grade,	87.9	1,485
Mountain Iron,	88.0	1,504

Part of Biwabik branch.

Iron Junction,	78.8	1,379
Summit, cut 6 feet; grade,	83.5	1,449
In sec. 4, T. 57–17, north of the west end of Cedar Island lake,	83.8	1,445

[The profile ended here. Jones, Weimar, etc., are stations on this line to Biwabik, and should be added.]

Mesabi Mountain branch.

Ore Junction,	81.1	1,402
Summit, cut 2 feet; grade,	87.0	1,457
Virginia (end of this branch),	87.8	1,438

[The iron mines, a mile distant to the east, are about 100 feet above Virginia.]

Duluth, Mississippi and Northern railroad.

[Taken from the profiles by Warren Upham.]

	Miles from Mississippi river.	Feet above sea level.
South end of the road, on the Mississippi river,	0.0	1,242
Swan river, water, 1,226; grade,	0.5	1,241
Highest level between the two crossings of Swan river; highest surface, 1,276; grade,	3.0	1,271
Swan river, water, 1,252; grade,	3.5	1,261
Swan River station,	6.7	1,293
Creek, bed (D. & W. crossing), 1,308; south edge of S. E. ¼ sec. 28, T. 53–22,	10.0	1,315
North part of sec. 16, T. 54–22,	12.8	1,418
Natural surface, 1,468; grade,	15.6	1,455
Natural surface, S. W. ¼ sec. 35, T. 55–22, 1,466; grade,	15.7	1,456
Grade,	16.6	1,417
Creek, bed, 1,391; grade,	17.2	1,405
Creek, bed, 1,360; grade,	18.7	1,369
Creek, bed, 1,350; grade,	19.3	1,366
Creek, bed, 1,338; grade,	19.9	1,345
Creek, bed, 1,336; grade,	21.0	1,347
Creek, bed, 1,339; grade,	22.6	1,349
Sand creek, bed, 1,367; grade (probably N. E. ¼ sec. 31, T. 56-21),	23.2	1,376
Grade,	25.0	1,417
Summit, in south edge of section 34,	29.3	1,509
Creek, bed, 1,482;	30.0	1,486
Creek, bed, 1,485;	30.2	1,491
Summit, natural surface, 1,523,	31.4	1,516
Creek, bed, 1,498,	31.9	1,503
Kelly lake, water, 1,499; grade (S. W. cor. sec. 15),	32.3	1,505
Grade is nearly level from 32.1 miles to 32.7 miles.		
Creek, bed, 1,502,	33.0	1,506
Owen lake, water, 1,503; grade (section 10),	33.7	1,510
Creek, bed, 1,504; grade (section 10),	34.0	1,514
Top of steep ascent from south, natural surface, 1,559; grade,	34.6	1,555
Creek, bed, 1,554;	35.0	1,558
North line section 3, natural surface, 1,562,	35.3	1,563

NOTE.—From Kelly lake northward the elevations here given are on the branch running through secs. 10 and 3, T. 57–21.

Elevations of lakes.

	Feet.
Crooked creek, on the international boundary,	1,251
Iron lake,	1,225
Lac la Croix, on the international boundary,	1,190
Loon lake,	1,161
Crane, Sand Points and Namekan lakes, on the international boundary,	1,121-1,120
Rainy lake, low and high water, 1,106-1,111; on the international boundary,	1,111
Embarras lakes (series extending about twelve miles),	1,380-1,353
Vermilion lake,	1,357-1,360
Trout lake, north of Vermilion lake,	1,370
Burntside lake,	1,370
Long lake,	1,337
Fan lake,	1,313
Garden lake,	1,384
Farm lake,	1,386
White Iron lake,	1,395
Birch lake,	1,410
Seven Beaver lake,	1,675

St. Louis river and its tributaries.

	Feet.
Embarras river, at the bridge of the Duluth and Iron Range railroad,	1,410
Lakes of this river, extending in a series about twelve miles, where it passes through the Giant's range,	1,380-1,353
Cloquet river, at the bridge of the Duluth and Iron Range railroad,	1,479
Small lakes forming the head of the St. Louis river in the west part of T. 59-11, about	1,685
Expansion of this river in Seven Beaver lake,	1,675
St. Louis river at the bridge of the Duluth and Iron Range railroad,	1,584
St. Louis river at the bridge of the Duluth, Mesabi and Northern railroad,	1,300
St. Louis river at the mouth of the Floodwood river,	1,234

Hills in northern part of St. Louis county.

	Feet.
Highest land in St. Louis county, in secs. 26 and 28, T. 59-17, northeast from Virginia, respectively, about	2,025-2,150
Summits of the Giant's range, T. 59-16, a few miles north of Biwabik,	1,800-1,900
Summits of the Giant's range near Hinsdale,	1,850-1,950
South ridge, at Tower, about	1,560
North ridge, at Tower, about	1,600
Chester peak, two and a half miles east of Tower, about	1,650
Grandmother hill, sec. 8, T. 57-13, about	1,775
Highest point on the Duluth and Iron Range railroad, summit of the Mesabi range, one mile north of Highland,	1,744

General topographic divisions and the drift. From the foregoing may be derived three general subdivisions of the area of this plate, viz.: (1) That part which is prominently characterized by bare rock and light drift. This area lies to the north and east of the Vermilion moraine; (2) That part which is characterized chiefly by coarse glacial gravels, with only occasional areas of till, and little or no rock exposure. This area lies between the Vermilion moraine and the Giant's range; (3) That part which lies south of the Giant's range, divisible into, (a) The till-covered portion, and (b) The muskeg.

These grand divisions have not always definite and abrupt limitations, but they are remarkably different when fairly established, each in its own area.

The Grant's range is the most striking topographic feature of the area represented by plate 67. It crosses the county entirely from east-northeast to west-southwest. The hills are mainly smooth in their sky-contour, and are quite conspicuous either from the lower land to the north or from the gabbro range (the Mesabi range)

which rises to about the same hight, about three miles to the south, where crossed by the Duluth and Iron Range railroad. The extreme hights are somewhat over 2,000 feet above the sea, and from 400 to 500 feet above the general level. At Birch lake these two hill ranges unite. Southwestwardly from that point the Mesabi range diverges from the Giant's range, passing to Duluth, but the *Mesabi iron range*, as known, follows the southern slopes of the Giant's range to the Mississippi river. The earliest development of the Mesabi ore was in immediate connection with the Mesabi range proper, and hence the name *Mesabi iron range.* At the present time the principal developments are near the Giant's range, many miles west of the point of their separation.

The first division above (1) is rocky and might in some places be styled mountainous. It is a well known feature of northern Minnesota, and was described by Nicollet as the "region of rocks and water," the lakes being connected by streams that run from rock-basin to rock-basin, overflowing one little valley after another, without perceptible gorge erosion. The waters are clear and abound in fish that frequent the northern latitudes, and the lakes are usually deep. The rocks are fresh, as if, after powerful abrasion, the glacier had retired from them rapidly, leaving very little drift. In the Vermilion valley, and indeed, so far as known, in nearly all of the valleys, northward sloping, is a scant deposit of fine clay, evidently the result of lacustrine deposition. This probably was originally formed over the rocky region when a glacier-dammed lake occupied it after the glacier began its retreat, but before it had uncovered the Rainy river outlet. It has generally been washed down from the hills into the valleys, and gives rise to occasional narrow swampy borders along the streams and lakes. The existence of the glacier margin at the place where the Vermilion moraine now lies is believed to have been contemporary with the highest stage of lake Agassiz, since the deposits of that lake reach eastward as far as the outlet of Rainy lake, where also this moraine crosses the Rainy River valley. There is a very marked change in the aspect of the country in passing from this rocky and forbidding area into that next to the west and south. This is apparent in the topography and in the vegetation, and at Koochiching falls it has been remarked by many travelers. Glacial striæ everywhere have a direction at right angles to the direction of the moraine. They are abundant and fresh. This conjunction of contrasted topography appears in Itasca county,* and it also runs further east with equal distinctness.

The Vermilion moraine, while sometimes quite characteristic, is not a large one. Indeed in some places it is only evinced by the general smoothness that supervenes, accompanied by the infrequency of rock outcrops. But the country to the westward is deeply buried under drift. How great a proportion of this may be of

* See plate 65.

till cannot be stated with any certainty, but it has been observed in several places that it extends but a short distance toward the southwest, and is replaced by copious deposits of gravel and sand which sometimes are rough and even hilly, and in other places are rather flat. Still further from the moraine the surface is flat and frequently swampy. Indeed this flatness is like that characteristic of the area of lake Agassiz, although the area of lake Agassiz is, so far as known, easily separable from the area which was not covered by that lake. This flat area of glacial gravel and sand lies higher than the flat area of lake Agassiz, which is apt to be clayey. Still, it remains yet to trace out carefully the area of lake Agassiz, in this part of the state, and to distinguish it from the plains of gravel and sand. It is not supposed that its water covered any portion of the area represented by this plate.*

The area (2) which runs to a point at the west end of Birch lake lies between two moraines, which converge and blend in one at that point. Such a situation, it can be seen, would be the scene of conflict and complication in the resultant drift sheet. While comparatively little is known of the drift in this area, derived from observation by the members of the survey, yet all the information at hand, as well as the general descriptive notes of the United States surveyors, warrants the conclusion that in general this region is covered by modified drift derived from the morainic areas that lie alongside of it, and at a date contemporary with the accumulation of those moraines.

It is probable, from general considerations, that the southern moraine was deposited later than the northern one,† being a marginal moraine of the lake Superior ice-lobe, which survived as a tongue from the continental ice-sheet long after the general withdrawal of the ice about the western end of the lake. According to Mr. Upham two continental moraines, which antedated the Vermilion moraine, coalesce in crossing St. Louis county, running approximately coincident with the Giant's range. But it is also possible, if not probable, that one of these, which would be the later one, was due to the lake Superior ice-lobe. Indeed there are certain alternations and superpositions of southern drift on northern, in the vicinity of the Biwabik mine, as well as further eastward, as described by Upham,‡ and as remarked by the writer about Birch lake,§ and in the valley of the Dunka river, that go to

*See the report on Itasca county, plate 65.
In reference to the location of the Vermilion moraine east from Vermilion lake, it should be added that Mr. Upham and Mr. Elftman are disposed to introduce a change in its direction and continue it northeastwardly, about parallel with the strike of the rocks between Tower and Ely. There is a noticeable amount of drift at Ely, and for a few miles westward, and also southeastward from Ely, which probably was the cause of the supposed extension of the Vermilion moraine to Ely and past the north end of White Iron lake. By the writer, however, these accumulatious are referred to a later date when there was another temporary halt in the retreat of the ice-border. This sub-morainic tract probably has its concave inner side turned more toward the east than the Vermilion moraine.
The prominent hill-range, seen south from Ely, consists essentially of a ridge of greenstone, and toward the west and southwest the drift is quite scant, the rocky structure being pronounced, as already mentioned, characteristic of the intra-Vermilion moraine surfaces.

†Compare the description of the Carlton county plate, No. 56.

‡*Twenty-Second Annual Report*, p. 44.

§*Sixteenth Annual Report*, p. 340.

show an extensive movement from the east or southeast after the formation of the continental drift-sheet. If a northern continental ice-margin lay here long enough to accumulate a moraine, it was necessarily much disturbed by the later movement from the lake Superior ice-lobe, and so wrought over that the present morainic ridge should be attributed to the later action, and should not bear the name of any earlier continental moraine. With that understanding, the term Mesabi moraine* might be continued, but it would obviously not be possible to carry it across the northern part of the state. On the other hand it would be found to shape itself somewhat as an appendage to the topographic outlines of the lake Superior basin, being the earliest of the independent moraines of that ice-lobe, but its southwestward extension and its connections with contemporary moraines further west and east are unknown.

There are morainic accumulations in considerable abundance about the north end of White Iron lake, which extend eastward past the north side of Farm lake, indicating a continuous morainic belt. It is probable that this is a later moraine than the Vermilion moraine. The eastward retreat of the ice-border was more rapid apparently at this latitude than at points further south, and faster than the northward retreat; and hence the later moraines are not concentric with the earlier. This is a subordinate ridge. It is probably crossed by the Portage trail from Long lake to Fall lake. Its further northwestward extension is unknown.

The area (3) is characterized by heavy drift, but in very diverse conditions. The till-covered portion (a) of this area includes roughly the eastern half of it. Throughout this tract there is much northern drift, referable to the Giant's range and to the country still farther north, but it also has a considerable amount of drift derived from the southeast and from the east. It is in general a more hilly country than the country to the west further, although there are some areas of considerable size that are flat, and covered with a muskeg similar to that which covers the western half of this area. This country is drained southwestwardly by a succession of northeast-southwest valleys and low ridges outlined in the drift. It is highly probable that this trend is given to the minor topography by a similar series of ridges and valleys wrought in the underlying rocks. It is a topography which enters the state with the Animikie in the northeast, where the rocks are not buried under a drift-sheet, and it seems to express itself on the final contours of the drift-sheet where the rocks are covered. This is complicated by a more or less irregular series of dikes and sills of the gabbro which permeates the Animikie from Pigeon point to Duluth; but, notwithstanding both the gabbro and the drift, the original rock surface is imperfectly outlined still by the little ridges and valleys which lie in the same direction,

*The Mesabi moraine actually lies on the rock range known as the Giant's range (of granite) and was first noted by the writer in crossing it at the Embarras lakes in 1878, *Seventh Annual Report*, p. 12.

wherever the Animikie and the Cabotian are known to occur. In the area further west (b), drained immediately by the St. Louis river, the country is like that, much of which is found in the southern part of St. Louis county, viz.: a flat surface covered by swamp, locally known in Minnesota as muskeg. Here the trees are stunted or wholly wanting, and a vast cranberry marsh extends as far as the eye can discern, with interruptions by small knolls where a few spruce trees maintain a stunted existence, or even by still higher swells on which are aspens and birches. There is a slow, obstructed drainage toward the rivers that wind about in this swamp, and thus the water gradually seeps out of the swamp and passes to the St. Louis river. The immediate surface, below the swamp and the water, is a fine sand or gravel, or occasionally it is of till. This swamp is indicated on the plate by the conventional sign, but it must be understood also that there are irregularities that are not expressed on the plate. Sometimes the till is covered, furthermore, by a laminated fine clay, and occasionally patches of till occur well within the muskeg. Small patches of muskeg are found also further north and east, but as the till region is approached, the swamps take on a different character, probably because they are periodically dried in summer, and they are occupied by more or less of white cedar and by tamarack. If these muskeg areas were drained, and the muck removed, there would result a fine fertile tract of level land.

Terraced gravels. At Long lake, and about the southeastern borders of White Iron and of Birch lakes are terraces of gravel. The first rises to about 1,475 feet above sea level. It is a mere fragment of what was once probably a terrace that extended further east and north. The Ely cemetery is on this terrace. On the north side of Long lake is a lower terrace, rising only twenty feet above the lake. The terraces of White Iron lake are conspicuous on sections 23 and 26, T. 62-12, where they compose isolated plateaux by reason of extensive circum-denudation or "dissection." Their hight is about 1,500 feet, but reaches an extreme of 1,513 feet. The terrace along the south side of Birch lake, seen at Dunka river, rises to about 1,600 feet.

These terraced gravels are to be attributed to the dammed condition of glacial waters in these valleys at the time of the withdrawal of the margin of the ice from the Vermilion moraine.

Kames. About two miles west from Ely a conspicuous ridge of gravel is traceable, running a little south of west, having the form of a kame, not represented on the plate. It probably accumulated about the same time as the terraced gravels seen about the southwest end of Long lake, and indicates that the outlet of the glacial lake that covered the region was toward the west, passing over the lowest notch in the greenstone ridge which lies south from the cemetery.

The geological structure. Beginning with what may be assumed to be the oldest known rocks in this area, we find ourselves at some place in Archean time, repre-

sented by a rock which is now gneiss, now mica schist, an old fragmental recast in a crystalline mould, but showing still its sedimentary origin, and now a greenstone, so-called, of complex characters, the last being the oldest. The bedded, or sedimetary structure of this old gneiss and mica schist is very apparent in many places, but the details of the geology of those tracts best known are given in the special smaller plates, constructed on a larger scale, included within the area of this plate. The granites and schists of this rock series, pierced by eruptives, both acid and basic, each having two dates of intrusion, occupy the most of the area north of the Vermilion moraine, extending along the international boundary from one side to the other. An attempt is made on the plate to separate it into two general parts, viz.: that which is schist and gneiss and presumed to have been of fragmental origin, and that which is gneiss and granite and probably of eruptive origin. No effort is made to indicate the areas of later basic eruptives, but it may be said in general that the basic dikes and bosses are closely associated with the acid intrusives. Where the acid granites prevail will generally be found more or less of Archean basic dikes.

Rainy and Kabetogama lakes. Much of Rainy lake is in Itasca county. That portion which lies in St. Louis county has a monotonous uniformity of geology, being enclosed on the south shore by mica schist or dark gneiss, whose strike is from N. 60° E. to east and west. This rock also occupies the peninsula which separates Rainy lake from Kabetogama lake, except in small areas, as represented on the plate, where granitic rock takes its place. Sometimes this mica schist is interbedded with coarse gneiss, and also with more firm gneissic rock which is apparently a constituent of the schist. Sometimes this schist has a high dip toward the south, or even stands vertical, but occasionally it dips at a low angle, and even lies nearly flat, passing through an anticlinal structure. Such an anticline is evident in T. 70-20, where the schists swell upward over a boss of granitic rock dipping northwest and southeast. It was first noted here by H. V. Winchell,* and was afterwards illustrated by professor A. C. Lawson in his general section,† running across Rainy lake. Indeed it is probably true that the schists of the region generally swell over and about the granitic bosses that rise here and there and occupy the surface, dipping on all sides away from the massive rocks. Following is the description of H. V. Winchell:

"In the N. E. ¼ N. W. ¼ sec. 15, T. 70-20, the schist lies flat in thin laminæ or plates. For several rods along the water's edge the flat schist lies piled up six or eight feet above the water, like slabs in a wood pile (No. 193H). This continues around the point for some distance, becoming thicker and coarser. From here it goes on to S. E. ¼ S. W. ¼ sec. 10, in a rather confused and disturbed way, now dipping north, now south, and now lying flat. This seems to be the middle of an anticline, and in fact the dip soon becomes permanently to the north. Beds of gneiss are still seen in the schist, but here they, too, are broken and discontinuous. Around the point further beds of schist two and three feet thick dip N. 40° to N. 60°, the strike being N. 80° E. Some of the schist here is very rich in garnets (Nos. 194H and 194aH).

"On the N. E. ¼ N. E. ¼ sec. 16, and the S. E. ¼ S. E. ¼ sec. 9, T. 70-20, the schist is again flat. It rises twenty feet above the lake. There is a bed of gneiss which has come up through, with a dip N. 60°; and there are other small granite intrusions that lie flat and cut through the gneiss for several rods. In the S. W. ¼ S. E. ¼ sec. 9, T. 70-20, is bed of gneiss, three feet thick, that lies on the top of flat beds of schist all the way round the point.

"In the S. W. ¼ S. W. ¼ sec. 9, T. 70-20, the schist is still distorted and contains garnets and considerable biotite. The granite intrusions run more irregularly than usual through the schist in this supposed middle of an anticlinal. The shores are all much lower here than further east, and are inclined to be marshy. Veins of white quartz, two or three feet thick, are common in this locality.

"The schist in the S. ½ of sec. 7, T. 70-20, has a north dip varying from 60° to 80°. The strike is east. It is a little harder here than usual and contains quartz veins and garnets. The bedding is wavy (No. 197H).

"In the N. E. ¼ of N. E. ¼ sec. 12, T. 70-21, is the first large bed of gneiss that occurs along here for several miles. It embraces several masses of schist. It is porphyritic and quite gneissic, and contains much peculiar green mica, especially near the contact with the schists. It also contains a few garnets, and has quartz veins penetrating it. The schist near it has a strike N. 80°, and a low dip to the north (Nos. 198H and 198aH).

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* *Sixteenth Annual Report*, p. 421.

† *Report on the Rainy Lake district, Rainy Lake sheet.* Canadian Geol. Survey, Montreal, 1888.

"In the N. E. ¼ N. W. ¼ sec. 12, T. 70–21, the schist rises about thirty-five feet above the lake. It strikes N. 70° E. Long, grayish-blue crystals of *cyanite* are found in some quartzose veins near the water's edge. Some of the blades of this mineral are six inches long (No. 199H)."

Further descriptions of the geology of the region by the same observer are as follows:

"The schist in the S. E. ¼ of S. W. ¼ sec. 1, T. 70–21, contains many quartzose beds and one or two veins of quartz. There are numerous garnets in these beds (No. 200H).

"The walls of schist on the north side of the bay, in sec. 1, T. 70–21, have glacial scratches along the smooth, perpendicular sides in all directions, but the majority are nearly horizontal. Sometimes the mark curves around a point or corner of the rock and continues on the other side as if the ice conformed to the outlines of the rocky surface and walls.

"The mica schist in the N. E. ¼ sec. 6, T. 70–20, is in thick beds that strike N. 70° E. and dip N. 35° to 38°. Long, low reefs of this rock run out into the lake, and the shores are low. Few or no granite or gneiss beds are to be seen in this region. The schist is exceedingly uniform in the appearance and composition of its strata.

"The south side of the point in sections 31, 32 and 33, T. 71–20, is composed of mica schist in beds of different degrees of hardness and amount of mica, but which have a general sameness of appearance. At the end of the point is some porphyritic gneiss in beds running about N. 50° E. The general strike of the schist is N. 70° E; the dip N. 35°. In places there is a jointage structure that crosses the bedding and divides the schist into angular plates and prismatic forms. The south side of this point presents the long beds broken off in a succession of rows that resemble walls of masonry slanting a little to the north. The schist on the north side of the point in S. E. ¼ of N. W. ¼ sec. 33, T. 71–20, strikes N. 80° E., and dips N. 52° (No. 201H). Small quartz veins occur in it, running with the strike. The mica in some of the schist is in spots, and gives the rock a mottled appearance.

"No. 203H is hard mica schist from S. W. ¼ sec. 29, T. 71–20. It strikes N. 76° E. and dips N. 60°, more or less. The schist here has some appearance of being conglomeratic. It is in very thick masses that do not show any banded structure, as some of the schist does. A little further west, in the N. W. ¼ of S. W. ¼ sec. 29, T. 71–20, there are beds of schist that are hydro-micaceous, and have a wavy structure running with the bedding (No. 204H).

"Some of the beds in the mica schist in the S. W. ¼ of S. E. ¼ sec. 26, T. 71–21, are quite siliceous, with with finely granular quartz (No. 205H). The beds here are vertical, or have a high dip to the north, and the strike is about N. 80° E., but is becoming irregular and broken. No beds of gneiss are seen in the schist here. Quartz veins are numerous.

"On the point in the S. E. ¼ of N. W. ¼ sec. 35, T. 71–21, the mica schist changes gradually into a rock composed principally of augite (?). It has no apparent bedding and is quite massive for a short distance. The continuation of it is lost in the water. This change takes place in going across the strike from north to south, the strike being about east. Some of this massive rock contains glassy quartz in veins. The schist here is finely banded and dips N. 72°. Nos. 206H to 206fH are from this place.

"The point in the S. W. ¼ of N. E. ¼ sec. 34, T. 71–21, is composed of evenly-bedded mica schist. Strike N. 86° E.; dip N. 74°. There are no beds of gneiss here; but quartz veins eight inches to two feet thick, running with the bedding, are frequent. These veins are sometimes connected by cross-veins.

"The schist in the S. W. ¼ of the N. W. ¼ sec. 34, T. 71–21, contains both mica and hydromica. Strike is N. 84° E. Many of the strata have reddish veins of quartz running with the strike and scattered all through the bed. The schist is also garnetiferous (No. 207H).

"Some beds in the schist on the point in the S. W. ¼ of N. W. ¼ sec. 33, T. 71–21, are lighter colored and more siliceous than usual. Strike is N. 80° E.; dip is about vertical (No. 208H). The schist in this immediate vicinity is very thin bedded; and where the sheets have fallen over into the lake overlapping each other they look like shingles on a roof. These siliceous beds became felsitic in the N. W. ¼ of N. E. ¼ sec. 32, T. 71–21. Strike is N. 74° E., dip S. 60° (No. 209H).

"No. 210H is a sample of mica schist from the S. E. ¼ of N. W. ¼ sec. 32, T. 71–21. The beds here are about vertical; strike N. 74° E. Quartz veins are numerous, and boulders, of which we have seen very few, if any, in the last three townships, are becoming more plentiful.

"In the N. E. ¼ of N. W. ¼ sec. 31, T. 71–21, the schist is cut slightly by a greenstone dike six inches thick. The direction of the schist is about E. 10° S., and that of the dike is east, although it curves (No. 211H). This is the first greenstone dike seen since coming into this lake from Kabetogama.

"In the N. E. ¼ of N. W. ¼ sec. 31, T. 71–21, the schist contains several beds of light color that seem to be composed of small rounded quartz grains, biotite scales and larger scales of some opaque mineral, probably feldspar. The strike here is N. 74° E. The schist is also hydromicaceous. These light colored beds vary from an inch to two feet in thickness (Nos. 212H, 212aH and 212bH). In the N. E. ¼ sec. 36, T. 71–22, there are more of these siliceous beds in the schist; some of them are felsitic and some sericitic."

The shores of these lakes are thus further described by H. V. Winchell (Sixteenth Report):

"Near the east side of sec. 13, T. 70–22, the schistose gneiss strikes east and dips N. 48°. A good portage of about a mile connects Black bay with Kabetogama (*the lake that lies along the side*). On the portage in sec. 19, T. 70–21, ridges of gneissoid mica schist are crossed, which trend N. 70° to 80° E. (No. 160H).

"In the N. W. ¼ of S. E. ¼ of the same section, mica schist occurs interbedded with coarse gneiss. Strike N. 70° E.; dip N. 58°.

"In the S. E. ¼ of S. W. ¼ sec. 27, T. 70–18, the beds of schist have a dip S. 80°; strike is N. 84° E. The point near the centre of S. W. ¼ sec. 27, T. 70–18 is made of perfectly straight parallel beds of schist standing

nearly vertical. There are also a few beds of gneiss. Some of the beds have a high dip to the south. No. 176H from this place contains green muscovite.

"Biotite, muscovite schist is found in N. W. ¼ of N. E. ¼ sec. 28, T. 70-18, dipping S. 76° Strike is east. There are narrow beds of gneiss, granite intrusions and quartz veins in the schist here.

"In the S. E. ¼ of S. W. ¼ sec. 21, T. 70-18, the schist dips S. 73°. It contains a few thin beds of gneiss. Glaciation is N. 40° E. Strike is N. 88° E. Boulders are numerous here (No. 178H). A little way north is a granite intrusion that cuts the beds of schist considerably. It is four feet thick and contains coarse orthoclase and muscovite like the regular beds of gneiss. A few rods further north is another intrusion of granite having a general direction N. 50° E. It is quite coarse and is porphyritic in places. There is a gneissoid structure running directly across the intrusion, the minerals and the weathering both showing it plainly (No. 179H).

"The schists north of this for some distance are not so regular, but are more thickly bedded. They weather into irregular lumps and not into thin sheets as usual. There are occasional narrow, winding intrusions of granite about six inches thick, that seem to be filled with muscovite in plates half an inch to an inch in length.

"In the N. W. ¼ of S. W. ¼ sec. 21, T. 70-18, are numerous intrusions, all having a general trend of N. 50° E. to N. 60° E. They generally have a dip similar to the schist. They frequently contain large orthoclase crystals which have quartz in them, thus forming a graphic granite (No. 180aH). Some of the schist contains red beds in which all of the ingredients have a reddish tinge.

"Occasionally the intrusions are quite gneissic. No. 182H is a sample from one of them that winds around and cuts across the beds of schist, and is finally pinched down from thirty inches to two inches in thickness. Some of these intrusions are garnetiferous (No. 183H). There is a small rock island in the S. E. ¼ of S. W. ¼ sec. 21, T. 70-18, that seems to form part of a very large granite intrusion. It runs across to the north end of the larger island east of it, where it is about seventy feet wide. It trends N. 55° E. It is composed mainly of graphic granite, which contains coarse muscovite and garnets and becomes gneissoid in places (No. 184H). There are also large and small masses and bunches of silvery or light-greenish quartz and mica in fine grains and scales, arranged in fibrous rays. It occurs in considerable quantities in this locality (No. 184aH). Perhaps the term 'greisen' might be applied to this rock.

"Beds of gneiss are seen in S. E. ¼ sec. 20, T. 70-18, having a very gneissoid appearance and striking N. 60° E. They also contain the peculiar masses of quartz and muscovite (No. 186H).

"Just east of the last the schist is remarkably straight and smooth. Strike is N. 83° E.; dip S. 80°.

"On the point in the S. E. corner of S. W. ¼ of S. W. ¼ sec. 20, T. 70-18, is a curious example of the way in which the granite intrusions cut the schist and twist about in it.

"The beds of gneiss are quite coarse and contain considerable quartz and muscovite. The orthoclase is yellow. The schist about as usual. Strike N. 84° E.

"In the N. W. ¼ S. E. ¼ sec. 19, T. 70-18, are more large and small beds of gneiss. Some of them conform with the strike of the schist here.

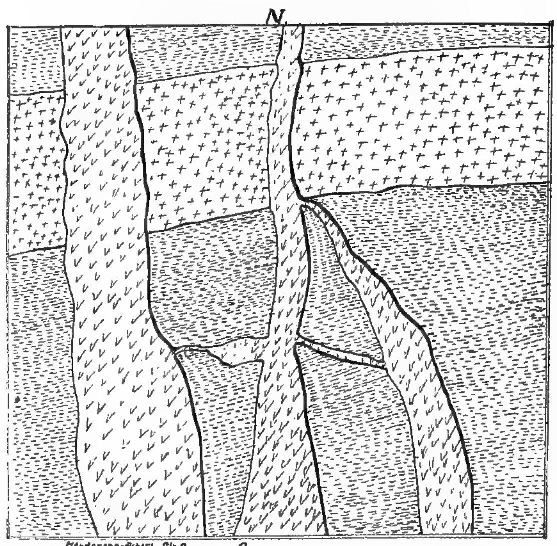

FIG. 22. GNEISS AND MICA SCHIST CUT BY GRANITE. LAKE KABETOGAMA.
S. E. ¼ sec. 31, T. 70-21.

"The beds of gneiss are quite coarse and contain considerable quartz and muscovite. The orthoclase is yellow. The schist about as usual. Strike N. 84° E.

"In the N. W. ¼ S. E. ¼ sec. 19, T. 70-18, are more large and small beds of gneiss. Some of them conform with the strike of the schist here. It is a little singular that all the intrusions observed for several miles east of here have a general trend N. 60° E. and the schist N. 80° E. Here the schist strikes N. 74° E. and dips S. 80°.

The beds or intrusions of gneiss still contain considerable quantities of the above mentioned radiated quartz and muscovite. About the centre of the west side of S. E. ¼ sec. 19, T. 70-18, the strike is N. 75° E. and the dip is 64° S. Here are large veins or dikes of coarse pegmatite, which contains immense crystals of pinkish feldspar intergrown with quartz to make a graphic granite. One crystal measured was thirty-three inches long, and many were seen over twelve inches. (Grant).

"At this place is a bed of gneiss that cuts across the schist for some distance, then comes into conformity with it and all at once splits up into thin beds an inch or two thick and becomes lost in the schist. It was over two feet wide at the start and maintained its thickness until it divided. These intrusions or beds of gneiss—for either name seems to fit at times—frequently enclose long strips of schist which sometimes maintain their usual strike and sometimes take that of the surrounding and enclosing rock.

"Sometimes the gneiss laps over and lies upon the edge of a good many beds of schist as if it had been squeezed up and out, and had flowed over. Most of it is porphyritic.

"In the S. W ¼ of S. W. ¼ sec. 19, T. 70-18, the schist occurs in beds, which average about two feet thick and strike N. 74° E. with a dip S. 82°. It is uniform and regular. There are large intrusions of granite running through it, N. 40° E. Part of the west side of a bluff has fallen into the lake and left a fresh break showing graphic granite containing muscovite. Each individual crystal of orthoclase seems to contain quartz grains running in the same direction through it according to some cleavage, or other natural tendency in the feldspar. Two crystals of orthoclase are never seen side by side with the quartz running the same way in both; but in each individual, however large, the quartz "characters" are all parallel or at right angles to each other (No. 187H).

"In the S. E. ¼ sec. 24, T. 70-19, the schist rises in bluffs twenty-five feet above the lake. There is also much gneiss here. Some of it contains large quantities of immense biotite scales. The strike of the schist here is N. 74° E., dip is S. 74°. The schist here is regular and uninterrupted, in perfectly even, thick beds for one hundred feet at a time.

"The point at the south line of S. E. ¼ sec. 23, T. 70-19, is composed of gneiss containing much of the quartz and mica masses and graphic granite. No. 188H is from a mass of the former two feet long.

"The N. E. ¼ of N. E. ¼ sec. 27, T. 70-19, is composed of mica schist, with a strike N. 76° E., and dip S. 80°, and large beds of gneiss. A little east of here the straight walls of mica schist, and, in one place, of gneiss, rise up thirty feet from the water's edge, covered with moss and lichens. The trees are mostly a thick growth of small spruce and Jack pine.

"The point in the S. W. ¼ of sec. 23, T. 70-19, is composed of mica schist and gneiss. The latter is full of radiated masses of quartz and mica in fine, glistening scales. It seems to have been pushed over the beds of schist in a plastic condition and to have a sort of horizontal gneissoid structure. It is quite coarse, and is porphyritic in places. The strike of the schist is N. 84° E.

"Fine-grained patches are often seen in these intrusions or beds of gneiss. The fine parts are often porphyritic, with perfect orthoclase crystals six to ten inches across. Frequently there are beds of pebbles and accumulations of boulders on a point or in some recess where there is a large bed of gneiss. These pebbles and boulders are principally of the same rock as that directly beneath and around them, and seem to have been formed right there by the action of frost and waves of the lake (No. 190H).

"The rock in N. W. ¼ sec. 20, T. 70-19, is principally mica schist. Strike is N. 70° E. Dip S. 80°, in thick beds (No. 191H). There are hard nodules in it, as there are most everywhere, that stand out in knobs and sheets and all sorts of odd shapes on weathered surfaces. It also seems to be cut by hard veins of matter which cross themselves and make a net-work of little ridges on the weathered surfaces. They do not seem to have any influence on the cleavage of the rock.

"In the S. E. ¼ sec. 19, T. 70-19, there is a bed of chloritic (?) mica schist in the other schist. It is four or five feet thick and contains much black mica in scales. It is cut off by an intrusion of granite which crosses the east end of it, and hidden by the lake on the west. Its general trend is N. 80° E. (No. 192H). There are hard veins running through it that seem to have been gneissoid, but now contain hornblende or chlorite and but little mica.

"The point of the island in S. E. ¼ of N. E. ¼ sec. 24, T. 70-20, is composed of garnetiferous gneiss, porphyritic with very large orthoclase, and containing quantities of the masses of mica scales and quartz grains. All of the large orthoclase crystals are pegmatitic.

"The mica schist in the S. W. ¼ of N. E. ¼ sec. 23, T. 70 20, strikes E. 40° S., dips S. W. 78°, and has glacial marks N. 46° E. It is in thick beds, and the mica is biotite. There are beds of porphyritic gneiss here, as everywhere in this region, only this has more of the radiated accumulations of mica and quartz. There is often a decidedly gneissic structure in these beds, but they are generally without it.

"The schist in the N. E. ¼ of S. E. ¼ sec.16, T. 70-20, is quite thick-bedded in nearly vertical strata. Strike N. 80° E. There are but few granite intrusions in this region, and the shores are lower and frequently covered with vegetation down to the water's edge. The lake at this time was unusually high. Streams of water were pouring into it on all sides from places where usually there is no stream at all. There was a cascade over each bluff, and a roaring little torrent down each ravine.

"On the portage in sec. 19, T. 70-21, ridges of gneissoid mica schist are crossed which trend N. 70° E. to N. 80° E. In the N. W. ¼ of S. E. ¼ sec. 30, T. 70-21, is mica schist mixed with coarse gneiss. Strike is N. 70° E., dip N. 58°.

"The small island in the S. W. ¼ of S. E. ¼ sec. 30, T. 70-21, is composed of interbedded mica schist and gneiss. The gneiss is quite coarse, is muscovitic and lies in thick beds. It contains also a little biotite (No. 161H).

"The mica schist in this region is often cut by beds or veins of black mica schist that weathers sooner than the rest of the schist. The gneiss contains pyrite and some small crystals of a black mineral like tourmaline. It also contains irregular patches of the schist.

"The point in the N. E. ¼ sec. 31, T. 70-21, is composed of interbedded gneiss and mica schist. The gneiss is often very coarse, containing mica crystals four inches long, and orthoclase six inches across (No. 165H). Both schist and gneiss are cut by intrusions of granite running in all directions. The general strike is N. 70° E., dip N. 45° to 50°.

"The S. E. ¼ of sec. 31, T. 70-21, contains a point nearly bare of vegetation, composed of rounded knobs of gneiss and mica schist, cut by granite intrusions. Some of the orthoclase crystals in the gneiss measure ten inches in length. The strike of the gneiss and schist is N. 80° E. The following diagram shows how the granite cuts the mica schist.

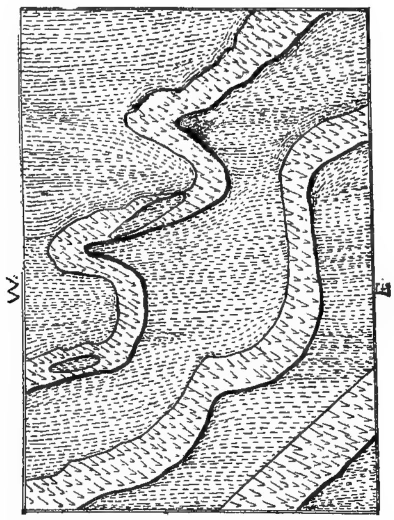

FIG. 23. MICA SCHIST CUT BY GRANITE, RAINY LAKE.
S. W. ¼ sec. 20, T. 70-18.

"In the N. E. ¼ of N. W. ¼ sec. 6, T. 69-21, is a bold bluff of gneiss, containing some mica schist. It is pegmatitic also (No. 162 H). The gneiss is very coarse, and contains large crystals of muscovite. It is a little peculiar that the mica schist, which is found in patches all through this gneiss, contains chiefly biotite mica, while the gneiss contains muscovite. There is some muscovite, however, in the schist, and a little biotite in the gneiss (No. 163H). The graphic granite here seems to be crystals of orthoclase, two feet or more in length, containing quartz. The surface of each mass of feldspar has one common cleavage, and reflects the sun as if it were one flat surface.

"Mica schist and gneiss are seen in the N. E. ¼ of N. W. ¼ sec. 8, T. 69-21. Strike is N. 80° E. There seems to be a tendency in all of this gneiss for the different constituents to separate from each other, and to collect as much as possible by themselves.

"Gneiss and schist are found in the N. E. ¼ of the N. W. ¼ sec. 17, T. 69-21. Strike is N. 80° E. Dip is north, at a high angle. When the beds of gneiss are thin the crystals are smaller than in the thick beds.

"Where the line between secs. 20 and 21, T. 69-21, crosses the shore-line there is a round hill of gneiss and mica schist that rises at least fifty feet above the lake. The feldspar weathers white on the surface, and makes the rock quite dazzling in the sun. There is less mica in the gneiss here; but the beds and included masses of mica schist are quite common. The strike is N. 70° to N. 80° E.; dip still to the north. No boulders are seen at the west end of this lake.

"Gneiss and mica schist, with an east and west strike and a dip N. 16° to 30°, occurs in the N. E. ¼ of N. W. ¼ sec. 27, T. 69-21. A few boulders lie along the shore here; but no drift covers the rock hills. Mountain ash trees are first noticed at this place.

"In the S. W. ¼ sec. 25, T. 69-21, the gneiss and schist still have a low north dip, 15° to 30°. The gneiss is sometimes porphyritic, and contains very black biotite (No. 164H).

"In the N. W. ¼ of N. W. ¼ sec. 30, T. 69 20, gneiss and mica schist occur in interbedded, thin, wavy or folded strata. Strike is E. 50° S. to E. 80° S., and with a low dip of less than 45° to the east. The character of the rock remains unchanged for a long distance east of here. It is always gneiss and mica schist in more or less distorted beds. Much of the gneiss is porphyritic, and contains large scales of both biotite and muscovite. The quartz is often chalcedonic. Most all of the large orthoclase crystals contain quartz, being thus pegmatitic. The beds become too much bent and twisted for any general strike or dip to be noted. The country is more wooded and hilly, and the rock comes down close to the water in perpendicular bluffs, over twenty-five feet high.

"There is such a mixture in the rocks that beds of any considerable length are not to be seen. Masses round, square, oblong, irregular, thin, thick, and in fact all shapes and sizes of mica schist, are seen in the gneiss where the gneiss predominates, and of gneiss in the schist where the schist is the main rock.

"Sometimes the strata lie in wavy, horizontal beds, and sometimes they stand nearly vertical. The gneiss is frequently porphyritic, and occasionally rock that approximates mica schist rather than gneiss is porphyritic, with feldspar crystals two or three inches long. The trees are Norway pine, white pine, Bank's pine, spruce, balsam fir, birch, aspen, great-toothed poplar, mountain ash, white cedar, willow, ash and elm.

"In the N. E. ¼ sec. 30, T. 69-19, there are beds of schist and gneiss that seem to be more regular, and have the usual strike and high dip to the north. The country through here is much wilder than that farther west. There is considerable good pine on the shores of the lake. The rock hills generally rise to a hight of fifty feet or more above the lake.

"Mr. Trussell examined the north shore of Kabetogama, through T. 69-20, up to Namekan, in T. 69-19. The formation is all the same—gneiss and mica schist in irregular beds. One specimen from the north side containing much biotite is No. 166H."

Namekan lake. This lake is thus described by H. V. Winchell: "The west end of Namekan lake is very beautiful. There are numerous points and islands, all heavily wooded down to the water's edge. The hills rise higher, too, in this region, and the bluffs have a bolder aspect. The rock is the usual gneiss and mica schist, the latter generally quite soft and crumbling, so that the gneiss is the rock that is most seen in all exposures.

"In the S. E. ¼ of S. W. ¼ sec. 26, T. 69-19, the gneiss and schist rise seventy-five feet in perpendicular bluffs, from which many large pieces have fallen down into the lake and left overhanging crags that have quite a picturesque appearance. There are pine and spruce trees growing in every available crack and crevice of the solid rock.

"In the S. W. ¼ of S. W. ¼ sec. 28, T. 69-19, the rock is more gneissoid than usual, and contains but little schist. It rises twenty-five to fifty feet above the lake on the islands and points in this locality. It is cut and re-cut by granite intrusions, but no trap or dioryte dikes are seen on this lake (Nos. 167H and 168H). The strike in N. W. ¼ of S. E. ¼ sec. 30, T. 69-18, is E. 70° S.; dip E. 45° to 60°.

"In the S. E. ¼ of S. W. ¼ sec. 28, T. 69-18, the strike is more regular and has returned to its general direction, N. 70° to N. 80° E., with a high dip north. Many mica schist beds occur in the gneiss, and serve to show the strike and dip better than the gneiss does.

"The gneiss in the S. W. ¼ sec. 26, T. 69-18, is fine and red, and contains very few beds of mica schist. There is a coarse, schistose structure running E. 60° S. (No. 169H).

"In the N. W. ¼ sec. 31, T. 69-17, the rock is almost pure mica schist. There are a few beds of gneiss, but the rock is largely schist, in thin, straight beds. Some of the strata are nearly horizontal, and some dip 60° or more to the east. The flat beds are folded and bent considerably.

"In the S. W. ¼ sec. 28, T. 69-17, the gneiss begins to appear again in thick beds, but the schist still predominates. The strike of the gneiss is about east and west, with a dip N. 40°.

"On the west side of the island, in the S. E. ¼ of N. W. ¼ sec. 29, T. 69-17, is a bed or dike of dioryte about twenty feet thick (No. 170H).

"The channel of the stream which flows from Sand Points lake into Namekan lake is one of the most picturesque spots seen in this region. The stream is deep and narrow, and runs between rugged bluffs of mica schist. The hills are covered with pine and the rocks with a luxuriant growth of lichens. The rocky walls are almost continuous enough to deserve the name of 'dalles.' They are all of mica schist having a general strike about east and west, and dipping about N. 45°. There are occasional beds of gneiss and veins of quartz.

"The rock on the island in the S. E. ¼ of N. W. ¼ sec. 21, T. 69-18, is gneiss and mica schist. The gneiss is fine grained, and contains irregular masses of schist. It is only slightly foliated (No. 171H).

"The entrance to Rainy lake is quite intricate, and is hard to find, as well as hard to keep when found. The plats do not follow the regular canoe route for the boundary, but take the north channel between Namekan and Rainy lakes, where a canoe seldom goes, because of the longer portage.

"There are two channels between these lakes, enclosing an island. The southern one has a chute of about nine feet, over mica schist. There is a good portage of about two hundred paces on the south side.

"The rock in this region is mica schist, with beds of gneiss. It is quite regular in bedding, strike and dip. Strike is N. 80° E., dip about N. 80°. The beds of gneiss are quite generally in conformity with the schist, but sometimes cut it a little (No. 172H).

"The north fall is about the same hight in one chute as the south fall. It is over fine, hard, brittle mica schist (No. 173H). This descent is known as Kettle falls. The schist is very evenly bedded, and stands nearly on edge. Strike is N. 84° E., dip N. 85°. The gneiss beds are very uniform, and are conformable with the schist. It is generally coarse, and contains garnets. Some of it, however, is quite fine, and shows the gneissic structure well. The mica in the schist is mostly biotite; that in the gneiss is muscovite. Some of the schist is hydromicaceous (No. 175H)."

The rock here presents a distinctly bedded appearance, due to what certainly appears to be sedimentation. A thin section of this rock (No. 1024G) shows that it is composed principally of quartz and biotite. Some secondary plagioclases appear much like quartz, being clear and glassy, in a manner quite similar to the secondary plagioclases of the schists about Vermilion lake (compare the Vermilion lake plate).

Sand Points lake. Mr. Grant made casual geological examination of the west side of this lake, and found it all occupied by the same granite or granitoid gneiss as occurs along the south shore of Namekan lake, excepting a small area in sec. 36, T. 68-17. The north-projecting point, N. W. ¼ sec. 36, is composed of granite and biotite gneiss. The granite cuts the gneiss in many directions. In places are large veins of very coarse, pinkish feldspar and quartz, often in the form of graphic granite. This granite is similar to that which pre-

vails eastwardly from this place, being as a rule medium-grained, and pinkish, with considerable biotite, with hornblende only in small amount. The area of mica schist which is represented by the Canadian report and map by Dr. A. C. Lawson as lying next east of Sand Points lake only appears, on the west of the international boundary, in a small area in sec. 36, T. 68-17, in the southeastern quarter of the section.

Between Sand Points and Namekan lakes is a current, but the descent is less than six inches. There is also a slight current between Sand Points and Crane lakes, the latter being two or three inches above the former.

*Crane lake.** Granitoid gneiss prevails along the west shore of this lake, without regular strike, and with no marked biotitic banding.

Vermilion river. This river is broad and steady from Crane lake to near the centre of sec. 22, T. 67-17, where rapids occur, over gneiss which strikes N. 80° E., with a dip S. 75°. This gneiss is variously mixed with mica schist and cut by granite. These rapids extend for more than half a mile, necessitating a portage of 1,450 paces. The ascent is forty-five feet as ascertained in the field by aneroid. At the upper end of the rapids the rock is granite, which continues to the point where the river crosses the section line between secs. 20 and 21, T. 67-17, where gneiss returns. This becomes somewhat schistose, with more mica, the same then being cut by intrusions of granite. A short rapids and a further ascent of eight inches are in N. E. ¼ sec. 20, T. 67-17, and another with an ascent of nine inches near the southwest corner of section 20. At the section corner is a rapid with an ascent of six and a half feet. The rock at both these places is gneiss, with a dip E.-S. E. 40° to 50°, the portage being 250 paces. Another rapid is near the centre of the N. E. ¼ of sec. 30, over gneiss (see plate T), with an ascent of twenty-one feet, and a portage of 200 paces. Gneiss continues thence through section 36, and into sections 35 and 34, having a dip about 45° toward the north. In secs. 2 and 3, T. 66-18, the river flows through a large rice swamp, with the gneiss exposed at several points on the right bank in section 2. The river is steady through sections 11, 10 and 15, except that a rapid spot, having about a foot ascent, occurs where the river passes from section 10 to section 15. A portage, however, is usually made in ascending, about three-fourths of a mile, in section 14, leading to N. E. ¼ of sec. 23. Just north of the centre of section 24 is a water-fall of nine feet, requiring a portage of 350 paces. The rock south from this fall continues gneiss. Through sections 23 and 24 the stream is narrow, with a decided current, contrasting somewhat with character of the stream further north, where the banks are lower, with occasional rice lakes on either side and noticeable current mostly confined to the rapid places. Gneiss outcrops at intervals through secs. 31 and 32, T. 66-17, the hill range further north in section 30 consisting apparently of granite.

Through T. 65-17 (not yet subdivided) the Vermilion is a good stream, 50 feet to 150 feet wide, with noticeable current, and very few rock exposures. These are of gneiss without regular dip or granitic gneiss. Along the long portage leading to the widening of the river in sec. 2, T. 64-17, is granite (No. 1056G). Sometimes the granite is coarser and sometimes finer than the specimen shows. The banks through T. 65-17 rise near the river from two to twenty feet, but the country rises much higher further back. Several small drift ridges are cut by the river. The banks have very few boulders, and are made of blue to yellow clay, *i. e.*, a laminated clay. The whole valley is good farming land. There is some oak and elm. The town has but little pine, apparently, the forest being mainly second growth poplar and birch.

In T. 64-17 the river widens out into a narrow lake, with low shores, largely swampy. Granite appears on the east side in section 24, and this rock continues, so far as can be determined, to the S. E. ¼ S. E. ¼ sec. 25, T. 64-17, where mica schist appears on the west shore, more or less cut by intrusive granite. It is also seen in the portage trail in section 36, and southward to Vermilion lake, where it constitutes the barrier at the outlet of the lake (rock 413 and plate S).

Little Vermilion lake and Loon river. From Sand Points lake there is an ascent of about a foot to Little Vermilion lake, with a rapid over mica schist. But southward from that point this lake is bounded by granite or granitoid gneiss. Southward from sec. 28, T. 67-16, this lake becomes a sinuous and narrow stream, with grassy, often marshy, banks, and is known as Loon river as far as to the outlet of Loon lake. There are two rapids in Loon river; one is at the crossing of the section line between secs. 2 and 1, in T. 66-16, with a fall of six inches, and the other is at the north side of section 1, where the level of the water changes by a fall of four feet six inches. There is a considerable fall (forty feet) over granite, at the outlet of Loon lake. The shores of Loon river rise from five feet to twenty-five feet, but higher land occurs toward the south. The banks are thickly timbered, with some good pine. It is a good, canoeable stream except in very low water.

Loon lake. This lake lies in a basin in granite or granitic gneiss, with moderately low shores, though frequently rocky. The water level ascends twenty feet from this to Lac la Croix, although only in very high stage is there any water passing from one lake to the other.

Lac la Croix has shores that are frequently rocky with granite, similar to the shores of Loon lake to a point as far north as the north side of sec. 8, T. 67-15. Eastward from there the shores are of mica schist, cut by numerous dikes of granite. This schist has a prevalent northerly dip, varying from 30° to 50°. This schist also includes the northern peninsula of Coleman island, but the southern portion is of granite. The lake has many islands. At the eastern extremity of the lake, *i. e.*, where the international boundary line leaves it, the portage passes for about half a mile over a granitic tongue (No. 1020G), known as Bottle portage, the water surface rising twenty-five feet to a small, nameless, granite-bound lake lying partly in sec. 35, T. 67-13.

Iron lake, lying toward the southeast further, in time of high water, has a slight discharge into the little lake last mentioned, but the volume of the boundary water goes to the east and north of Irving island into

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*The descriptions of Crane lake and Vermilion river and the international boundary to Crooked lake are based on the field notes of Dr. U. S. Grant.

Lac la Croix. At the east end of Iron lake are Curtain falls, where the change of water level, including about three feet at the rapids below, amounts to thirty feet, the water passing over granite. The accompanying view of these falls is from a photograph made by Dr. Grant in 1894 (plate T, figure 1). These falls furnish the outlet for Crooked lake, the level of which is even with their brink.

Crooked lake also lies in a basin in massive crystalline rock. The course of the international boundary was examined in 1887, by Dr. A. Winchell, as far west as Iron lake. The shores are frequently lined by massive outcrops of crystalline rock, essentially granitic, which in the background rises into bald knobs, which are often red, with the prevalence of reddened feldspar. A specimen from the red granite at Curtain falls affords a thin section which contains, along with quartz and mica, both orthoclase and microcline. This is rock No. 286W. Although granitic, these rocks have a coarse and irregular bedded structure, and in many cases they would be styled gneiss, but not a banded gneiss which could be considered a sedimentary rock crystallized *in situ*. Near the rapids, just below the falls, are many large fragments of mica schist, indicating the near proximity of the boundary of the massive rock. These are visible on the Canadian side. Curtain falls are represented on plate T.

Net lake, lying mostly in Itasca county, has mostly a swampy coast line, and is shallow. Mica schist outcrops sparingly in the midst of the Indian village at the east end of the lake. The same is seen on a small island near the village. Here it is interbedded with gneiss and cut by granite dikes, and the whole is cut by a large dike of greenstone, containing much magnetite, from which stringers penetrate the other rock. The schist strikes N. 58° E. and dips about S. 70°, and the dike runs about north and south.

Pelican lake has a shore line of drift materials, with occasional rock outcrops.

Pink gneiss is found in the N. E. ¼ of S. W. ¼ sec. 2, T. 64-20. It grades into mica schist in the immediate vicinity. The apparent dip here is south, but there is so little continuity in strike or dip that the general direction cannot be determined (Nos. 306H and 307H). The south side of the point at the same place consists of beds of mica schist and gneiss that dip west and strike north and south. The schist is hard and fine-grained; the gneiss gray and fine (No. 308H).

The island in the N. E. ¼ of S. E. ¼ sec. 3, T. 64-20, is composed of gneiss and schist and granite intrusions. The schist is both micaceous and hornblendic. The general strike is north and south, with a high dip to the west. The surface of the rock presents a most intricate commixture of veins, dikes, beds of schist and gneiss and granite intrusions. The last thing to come in was a small dike of greenstone about three inches wide, running N. 30° E. It cut all the rest, but has been faulted off two or three feet since, and thus been changed in its direction.

Samples from the dike are No. 309H. It was traced for about three rods. At the same place there is a band of greenish rock composed of mica, hornblende, feldspar and perhaps quartz, running through the rock in an east and west direction. Streaks or threads of gneiss run all through and across it, and give it a mottled appearance. It is about six inches wide, and can be traced in a straight course for five or six rods. It maintains about the same thickness during this distance. Where it passes through schist there is generally a line of granite to separate it from the schist. Where it cuts gneiss there is no distinct line of separation, but the gneiss runs right down into it in the threads spoken of above. The dark parts of this band of rock have a kind of schistosity in the direction of the vein.

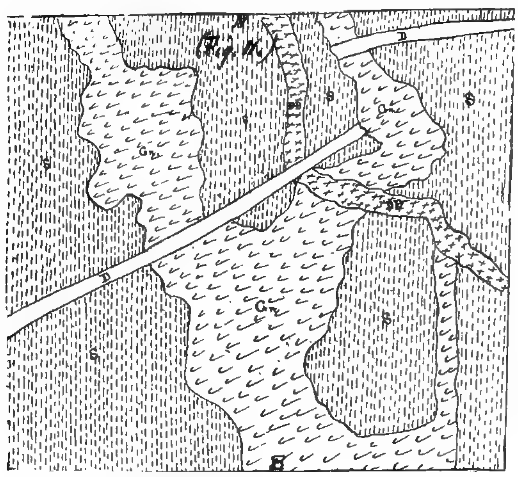

FIG. 24. PELICAN LAKE.

Gn.—Gneiss. S.—Mica and hornblende schist.
D. B.—Granite intrusion. D.—Small dike of greenstone.

The island near the centre of sec. 3, T. 64-20, is composed of the same mixture of gneiss and schist, and rises fifty feet above the lake. There are long, smooth beds of rock which is half gneiss, half schist, on the west side of the island. These beds strike north and south and dip W. 64°. Much of the schist contains both hornblende and mica, and some of the gneiss is syenyte gneiss. Occasionally dark, hornblendic rock is seen, just as

much bedded as the rest and evidently part of the formation, but looking much more like eruptive rock. Some of it contains round grains and feldspar that look like amygdules (Nos. 310H and 310aH).

In the N. E. ¼ sec. 12, T. 64–21, the rock is massive gneiss. The only signs of mica schist are a few small lenticular masses of it, four to six inches long, which are enclosed in the gneiss. The rock is in low, flat outcrops. It contains hornblende and is somewhat porphyritic (No. 311H). It does not exhibit any granite intrusions nor other rock cutting it in any way. The same rock appears on the next point to the west, and here contains masses of mica schist, twelve to fourteen inches long. It is also more porphyritic, containing orthoclase crystals one and a half inches long.

The point in the N. E. ¼ of N. W. ¼ sec. 12, T. 64–21, is composed of this same rock. It contains a few masses of hardened mica schist two or three feet in diameter.

(No. 312H). This rock is very similar to that which forms the falls at Fort Frances; the points of resemblance being its porphyritic nature, the presence of hornblende crystals as well as mica, no gneissic structure apparent, enclosed masses of mica schist, and position to the west of a disturbed region of gneiss and mica schist. It is probably the continuation of the same belt of rock as that at Koochiching falls. Immense, rounded pieces of this rock lie on the surface, some of them twenty feet in diameter.

No. 313H is siliceous gneiss, coarse, granular and white. It occurs in thin beds in the mica schist on a point in the N. E. ¼ sec. 35, T. 65–20. On one side of it is mica schist with the biotite in round spots. The strike of the gneiss and schist here is north and south; dip at a high angle to the west. The gneiss predominates and is largely in thick beds. Both gneiss and schist are penetrated by granite intrusions that run for the most part east and west. These are very siliceous, contain white orthoclase and have an indistinct gneissic arrangement of the mica (No. 314H).

A small island supposed to be about in the S. E. ¼ sec. 26, T. 65–20, is composed of gneiss and hornblendic mica schist. Strike is N. 30° E., dip N. W. 75°, more or less.

The beds of hornblendic mica schist are more decomposed than the rest of the schist.

One of these beds of schist cuts into the mica schist proper in some of its curves, for it is not quite straight, though it follows closely the bedding of the mica schist, and is cut by the same granite intrusions as the mica schist (No. 316H). The specimens are from the hardest part of the bed, which is about six inches thick and has a gneissic arrangement of the minerals.

The next point to the northwest, about a quarter of a mile, is composed of gneiss and schist, the latter containing more or less hornblende all through it. The strike varies from N. 30° E. to N. 50° E. There is a high dip to the northwest. The schist is dark, hornblendic rock containing vitreous quartz grains and apparently but little feldspar (No. 317H). Some of the schist is harder and finer and less schistose than the samples. Much of it contains fine particles of pyrites.

The extremity of the point consists almost wholly of gneiss enclosing large masses of schist. Some of the gneiss is quite coarse, containing feldspar crystals over two inches long. Much of it looks like the coarse gneiss seen on Rainy lake, and some of it is pegmatitic. The finer gneiss contains hornblende as well as mica.

On one point in sec. 26, T. 65-20, the gneiss contains pockets of amphibolyte (?). They are round or irregularly shaped masses that have no resemblance to the gneiss and no visible connection with the schist beds or any other beds. They are simply enclosed in the gneiss. No sample could be obtained.

Just across the bay from the last point, to the north, the rock of the point is half way between mica schist and gneiss, but looks on the whole more like schist. It contains and lies alongside of beds of hornblendic mica schist such as is commonly found imbedded with gneiss in all this region. They are both cut by intrusions of granite. Thus we have here, instead of gneiss proper folded around mica schist or squeezed into it in a plastic state, mica schist—for it is that rather than anything else—enclosing and interbedded with irregular masses and strata of entirely different mica schist (No. 318H). This is somewhere near the N. W. ¼ sec. 26, T. 65-20. The general strike is about N. 20° E.

In the bay north of the last is a small rock island composed principally of gneiss. The enclosed mica schist is like No. 318H, and not like the more schistose schist with which that is associated. The schist and gneiss on this island are cut by an irregular intrusion varying in width from four to ten inches. It is noticeable that the intrusions which seem to have been latest and have cut all the rest are generally pinkish or reddish; while the bedded gneiss is white or but slightly pinkish, as a rule; though some of it is red rather than pink.

On this same small island the gneiss that conforms with the beds of schist for a short distance and is cut by the granite intrusion mentioned above, in its turn strikes off in a mass two feet and more in thickness, cutting through the schist—or at least across the strata—and constituting what might be termed a "dike-bed" without being paradoxical.

The south side of the small island just west of the last is composed for the most part of handsome gray gneiss, slightly porphyritic. It is cut by the usual granite intrusions. No. 319H is a sample.

On the shore of the mainland about 100 paces north of the island the rock rises thirty feet above the lake. It is mica schist and syenyte gneiss with granite intrusions. It contains varying amounts of hornblende and grades in places from syenyte to a dark, heavy, fine-grained rock almost all hornblende. It seems to contain some epidote (No. 320H).

For some distance along the shore to the west the rock is syenitic gneiss and mica schist. A little farther along some immense masses of schist and gneiss stand up in the water near the shore, fifteen feet above the surface. They seem to have constituted one enormous boulder, now split and broken into several irregular, jagged masses.

The large island southwest of the last-mentioned locality presents an appearance similar to that of the coarse gneiss at the east end of Rainy lake. It is a mixture of coarse gneiss and mica schist. The schist predominates at the southwest end of the island. The strike is N. 20° E., dip W. N. W. 70°. The backbone of the island is principally gneiss, containing a little mica and hornblende schist in irregular masses and short beds. This gneiss is very siliceous, the coarse, vitreous quartz lying in it in masses several inches across. The feldspar is pink or white orthoclase, and is also very coarse, the largest crystals being over six inches long. The mica is muscovite; and scales two inches square can be obtained.

The gneiss incloses masses of hornblende schist. Samples are No. 321H. The mixture of mica in fine scales, and quartz in small grains, such as seen at the east end of Rainy lake, is found here, too. Some of the large feldspar crystals here contain quartz arranged in such a way as to form graphic granite. At the northeast end of the island there are siliceous beds in the schist containing pyrite, hornblende, malachite, chalcopyrite and a greenish-yellow mineral that was not determined (No. 322H). These beds are a foot or two feet wide, and continue for some distance, disappearing under the lake. The coarse gneiss here contains some biotite, as well as muscovite.

On the large point west of here is found the usual mixture of gneiss and mica schist both containing more or less hornblende. Strike is N. 35° E. Some of the schist enclosed in the gneiss has been so much changed and resembles the gneiss so closely that one is hardly able to discern the outlines of the former schist masses. Much of it is exceedingly hornblendic.

On the hill north of the point there is a breccia. It is a gneissic schist containing angular masses of hornblendic schist of all sizes up to two or three feet in diameter. Many of them have their longest direction across the schist beds. They seem to be much metamorphosed. The breccia also contains pieces of gneiss a foot long.

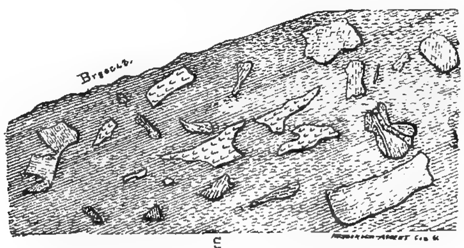

FIG. 25. BRECCIA. PELICAN LAKE.

There are also in this breccia pieces of schist with gneiss running through them. There is a schistose or flowage structure running N. 35° E., and conforming somewhat to the shapes of the enclosed masses. This breccia extends nearly to the south end of the point.

The island just west of this point is composed mostly of micaceous, porphyritic syenyte very poor in silica. It is massive and contains large irregular masses of mica and hornblende schist and gneiss. It has a contact with rocks similar to those enclosed in it, on the east side. The direction of this contact is N. 20° to N. 24° E. In some places this rock resembles a coarse breccia, and elsewhere a conglomerate, the faint outline of formerly enclosed masses being visible. It has the appearance on the surface of having been heated to a boiling condition, and the uneven surface covered with curved lines and half-broken bubbles reminds one of oat-meal when cooking. It is cut by one or two narrow granite or rather granulyte intrusions. It also contains a few masses red granulyte wholly enclosed in it. When it has been washed and weathered by the lake a schistose structure or something similar appears, the rock weathering in wavy lines and sheets.

The small island nearly a mile west of the last consists of pyritiferous, micaceous, garnetiferous, chloritic (?) syenyte gneiss. The rock that lies to the west of this and is similar to the Fort Frances rock grades into this and into rock more hornblendic than this. This rock is all laminated in thin sheets having a low dip to the north (Nos. 325H and 325aH).

In sec. 36, T. 65-21, the whole shore, where it is high, is formed of the Fort Frances rock and its variations. The main part of it is quite similar to that which forms the falls at Fort Frances, but much of it is similar to No. 325H. It contains masses of pure, unchanged mica schist ten, twelve, and even forty feet across. This schist is cut by granite intrusions and stands for the most part in vertical beds. Some of the mica schist inclusions are very much smaller, only six inches wide and two feet long or less. The schist has a very abrupt contact with the rock in which it lies. There are also inclosed in this rock numerous rounded and irregular pieces of rock quite similar in appearance to the main part of the rock, but generally more hornblendic. The inclusions are porphyritic and in other ways have a close resemblance to the rock which contains them, and yet they are decidedly different and probably were much more so formerly. The granite intrusions may be, and probably are, stringers from the main mass of the rock. The mica schist which is contained in this rock has small round "geodules" on the surface. They are little geodes having a quartz crust with garnets inside. One inclosed mass of schist is cut by a small dike of trap which has a slight schistose structure.

In the N. E. ¼ sec. 35 (?), T. 65-20, the gneiss and mica schist are cut by granite intrusions. Some of them are garnetiferous. Tourmaline crystals were found in the gneiss which is interbedded with the schist at this point. The rock is mostly fine gneiss. One of the large granite intrusions on the east side of the point consists largely of pegmatyte. This looks much like the coarse gneiss seen at Rainy lake. The trend of the

graphic granite intrusion is N. 25° E.; width, 6 feet; length of exposure, 150 feet. It contains muscovite crystals two and a half inches across (No. 331H).

In the N. W. ¼ sec. 36 (?), T. 65–20, the rock is principally mica schist and interbedded gneiss. Irregular masses of a greenish heavy rock, consisting mostly of hornblende, are contained in the gneiss. These masses are not over two feet long, and have an abrupt contact with the gneiss.

In the N. E. ¼ sec. 36 (?), T. 65–20, the rock is principally mica schist containing some very even beds of gneiss and cut by granite intrusions running directly across the strata.

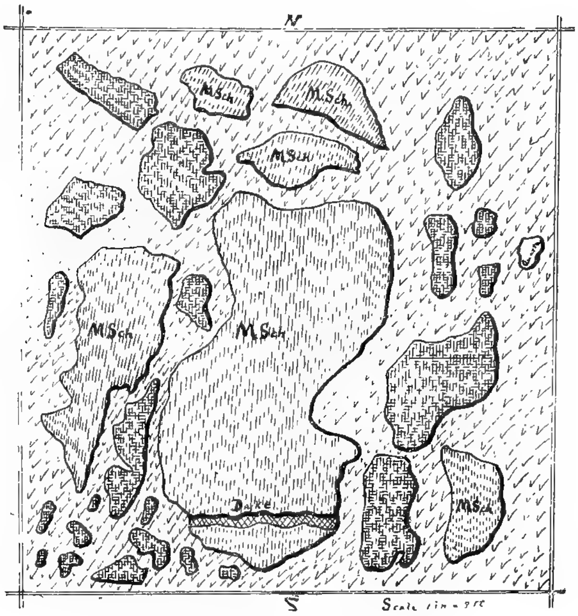

FIG. 26. BRECCIA. PELICAN LAKE.

Elbow lake and river. A small stream leaves Elbow lake, and, after tumbling down a winding glen around boulders and over solid rock for about a quarter of a mile, becomes a small river with apparent current most of the way to Pelican river, into which it flows. This is Elbow river. There is a high ridge of hills south of it, and considerable high rocky ground north of it. When any large amount of rock in this region has a uniform strike, it is about east and west. All of the rock around Elbow lake contains more or less hornblende, and most of it is decidedly acidic. The south shore of Elbow lake follows the changing strike of the rock quite closely.

Going down Elbow river the first rapids is just at the outlet of the lake. The next is two and a half or three miles below. The hills here rise about 200 feet above the river on each side. They are almost bare knobs of gneiss containing more or less schist interbedded with it. The hill on the north side of the rapid is called Bald mountain.

The country for a few miles around, as seen from the top of Bald mountain, is rough and hilly, and probably all composed of the same formation. There is generally a strip of swamp along the river. The river bed is remarkably level for such a hilly country. Elbow river flows into Pelican river about two miles south of the east bay of Pelican lake, sec. 18, T. 64–19. Samples of the gneiss from the top of Bald mountain are No. 304H. The mica schist from the same place is No. 305H. The gneiss is hornblendic or chloritic, and is a fine-grained siliceous rock with fine veins of light green mineral running through it.

Burntside lake lies within the "rock and water" area. Its shores are usually composed of bare rock, frequently glaciated and rounded into low domes of gneiss and mica schist. Its water, which drains eastward through Long lake, is clear and abounds in excellent fish. The lake contains many islands. It is one of the most beautiful lakes of Minnesota. "Some day the pleasure seeker will discover the charms of Burntside lake to exceed those even of the Thousand islands in the St. Lawrence."* Plate U, figure 1, represents a view on Burntside lake. About this lake are unsurpassed opportunities for studying the nature of the transition from the Keewatin to the Coutchiching and to the gneisses, as well as the nature of the granitic intrusions which pierce all these. About the west end of the lake are bold bluffs which are essentially composed in the first instance of mica schist, but are intersected by later granitic veins, the dip being sometimes toward the north 60°, or again toward the south 60°. There are alternations of granitic dikes, sometimes forty feet wide, with mica schist, the latter being very fine and compact, and apparently derived from a gradual transition from graywacke. The granitic veins and intrusions have a tendency to conformity with the schists, but they split and swell and branch in every conceivable manner. The granite is mostly with very little mica. The swellings and some of the small concretions are coarse granulyte in which quartz is very conspicuous and sometimes almost entirely

*A. WINCHELL. *Fifteenth Annual Report*, p. 27.

FIG. 1. VIEW ON BURNTSIDE LAKE. (p. 246.)

FIG. 2. VIEW OF THE AGGLOMERATE IN GREENSTONE AT ELY. (p. 255.)

displaces the orthoclase. In other places the mica schist is so cut up by intruded granite that half the mass is granite. The accompanying sketch (figure 27) represents the relation of the granitic dikes to the schists at N. E. ¼ S. E. ¼ sec. 21, T. 63-13, at the southern point of the large island.

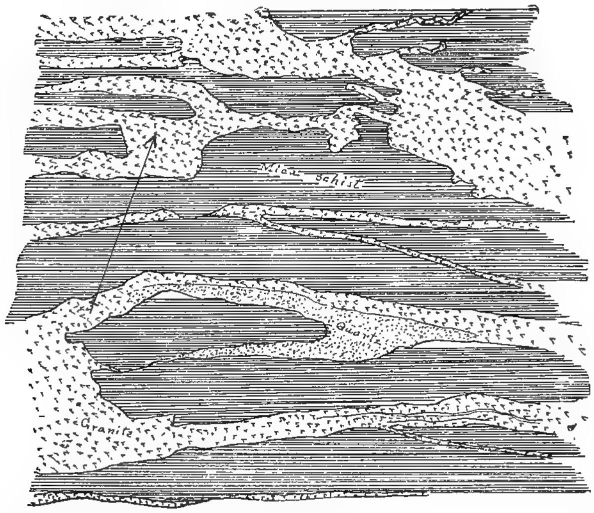

FIG. 27. RELATIONS OF MICA SCHIST AND GRANITE. BURNTSIDE LAKE.
Surface 12 feet square.

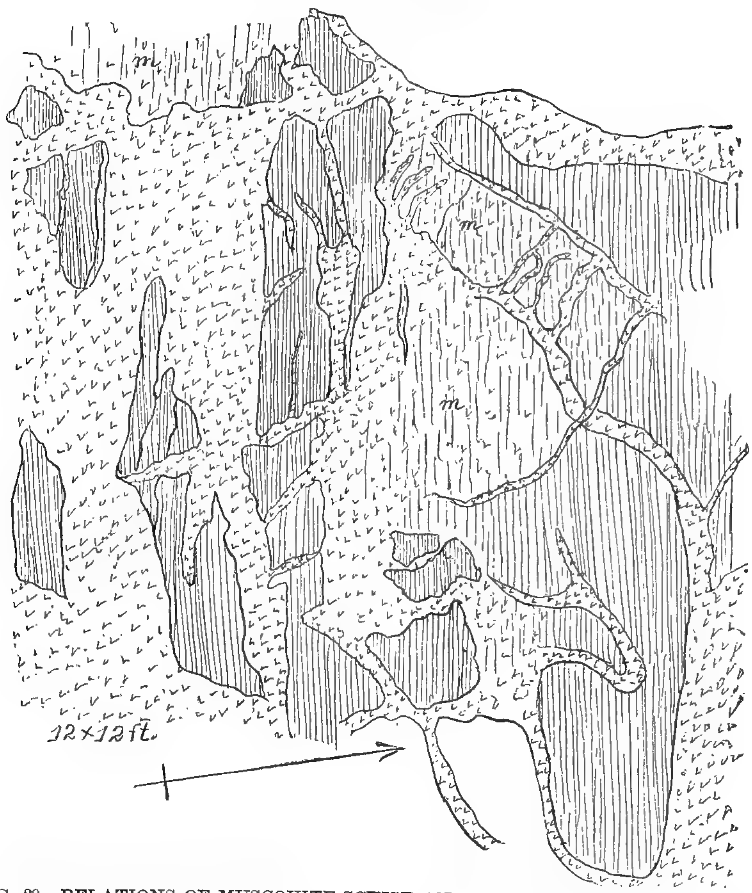

FIG. 28. RELATIONS OF MUSCOVITE SCHIST AND GRANITE. BURNTSIDE LAKE.
In the regions marked M the schist and granite are intimately mixed.

On the N. W. ¼ N. E. ¼ sec. 21, T. 63-13, on the same island, the formation is largely taken up with intruded granite. There is a distinct tendency of the granite to conform with the schistose structure, but it is nowhere exact. It lies in some places in great masses, and is of two kinds,—one with reddish orthoclase and one with a whitish,—but these do not appear to belong to two systems of injection. In the former feldspar much

exceeds the quartz. In neither is mica conspicuous, even when present. Notwithstanding the abundance of granite, the mica schist is everywhere distinctly laminated.

The granite and schist are mingled, not only through abundance of granite injections, but by much interpenetration on a small scale. Portions of the rock are so ribboned with granitic and schistose ingredients irregularly succeeding each other that the rock is literally schisto-granitic.

The appearance of this area indicates a gradual passage from mica schist into granite, not mineralogically but structurally. The lamination of the schists is often locally bent by the granite. The strike of the schists is N. 82° E. (figure 28).

On the main land, S. W. ¼ S. W. ¼ sec. 23, T. 63-13, is a boss of compact mica schist, in places having hundreds of veins of epidote crossing it conformably with the lamination; also with many veins of quartz similarly conformable, and others transverse to the structure. There are also veins of epidote that cross the structure. The strike here is N. 63° W., and the dip is southerly.

There is a rounded point of the mainland on N. W. ¼ S. W. ¼ sec. 23, T. 63-13, on the south side of the lake, which consists very largely of a mass of granite, but little schist being discoverable. This is a medium-grained biotite granite. This is intersected by two systems of granitic veins. one of which is fine-grained, with little mica, and the other a granulyte. Of mica schist the only example found is about two feet wide. It is fine-grained, compact and brittle. It forms on two sides a sharp junction with the granite, but is in places penetrated by granitic intrusions. It approaches the character of fine gneiss. It runs about sixty feet, visibly, in a direction N. 71° E.

There is a great mass of dark hornblende schist (No. 69W), with considerable feldspar, near the centre of S. W. ¼ sec. 23, T. 63-13. It is intersected by quartzose veins, mostly conformable with the structure; also by a dike of fine light-colored muscovite granite, two and a half feet wide (No. 70W), which runs N. 51° E. The schist strikes N. 69° E., standing nearly vertical, but dipping southerly. Adjoining this toward the south the rock assumes the character of a syentye gneiss, being, however, still a massive hornblende schist. In this part is a granite vein nine inches wide, running with the strike, and having itself, on the weathered surface, structure lines parallel with the structure planes of the schist. This vein is faulted twelve inches, and terminates abruptly in its eastward extension. It is not a proper granite, but a compact, fine-grained gneiss.

At the centre of the S. W. ¼ sec. 23, T. 63-13, is mica schist intersected by many veins of granite, granulyte and quartz. Embraced in the mica schist is a mass of light-colored granulyte surrounded by the schist on all sides and embracing fragments of the schist which still retain their laminated structure and their original positions, as in the figure below. The granulyte also contains a layer of muscovite hornblende schist.

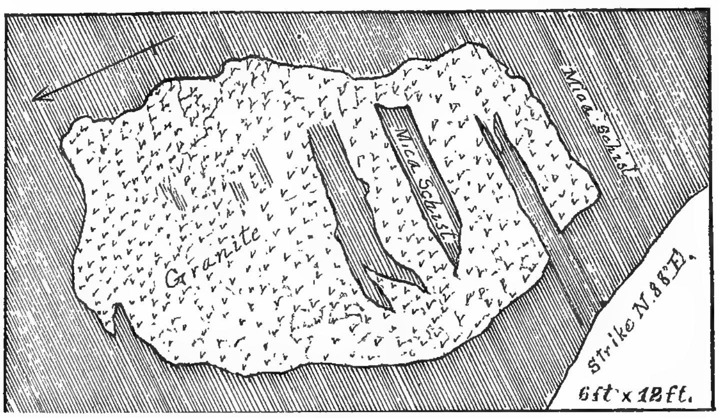

FIG. 29. SCHIST INCLOSING GRANULYTE, ITSELF EMBODYING MICA SCHIST. BURNTSIDE LAKE.

The rocks of Burntside lake show great variety, both in mineralogical composition and in structure. Many petrographic details will be found in vol. v., Petrographic Geology.

Near the centre of sec. 8, T. 63-12, is a granite, fundamentally hydromica granite of light color, but extensively intersected by dike-like beds of dioryte-like hornblende schist, and including some dark chunks of fibrous hornblende schist. This sort of granite continues southwestward along the lake shore. On the north side of sec. 18, T. 63-12, it contains many large quartz grains. A massive, handsome rock, suitable for fine architecture and monuments, occurs about twenty rods south from the end of the island (No. 74W), N. W. ¼ N. W. ¼ sec. 18, T. 63-12. It is coarse-grained, consisting of hornblende and a pinkish feldspar.

At the N. E. ¼ N. E. ¼ sec. 13, T. 63-13, is a rock which is mostly a hydro-mica granite, with coarse disseminated grains of quartz. The longer dimensions of these grains lie in the direction N. 60° E. It is intersected by many veins of granulyte, with reddish orthoclase. In some detached masses of granulyte some portions are of reddish feldspar, and others of whitish, and other portions are extraordinarily coarse. There are also rounded masses of hornblende schist. Near this place is a mass of granulyte very variable in texture and presenting still further varieties in its veins and dikes. As exposed on the shore in a nearly vertical wall, it has the

appearance of the ordinary laminated schists, dipping north at an angle of 70°. This illusory appearance is due to joints, which, with another set making an angle of 75° or 80° with these, give the formation a columnar appearance.

There is much confusion and mingling of rock of different types at the points of transition from the massive rock to the schistose. This is exemplified on sec. 12, T. 63-13. The formation becomes somewhat nondescript, consisting of perhaps one-fourth interbedded granite, nearly three-fourths slightly micaceous hornblende schist and the remainder of syenitic gneiss and granular dioryte. In this mixed state it trends northeast and forms a rocky range on the north side of the bay, attaining an altitude of fifty feet. The structural relations exhibited by the following figure were sketched from the face of the bluff S. E. ¼ S. W. ¼ sec. 12, T. 63-13. The formation is about half granite and half mica schist.

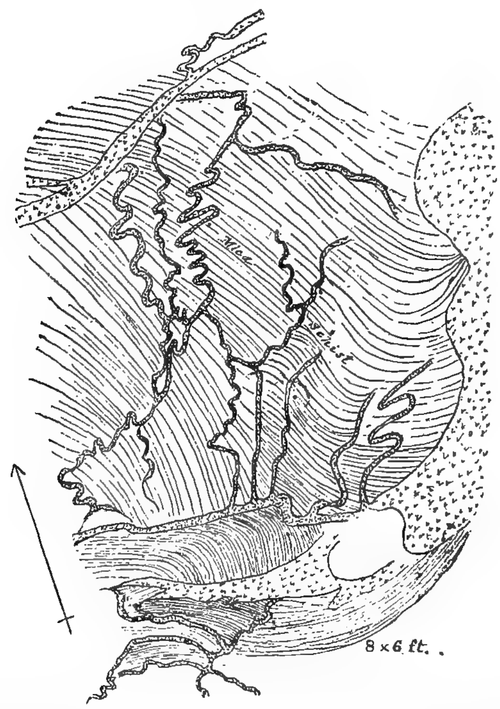

FIG. 30. VIEW OF REMARKABLE ROCK STRUCTURE. BURNTSIDE LAKE.
S. E. ¼ S. W. ¼ sec. 12, T. 63-13.

The relations of the granite veins to the mica schist seen in the last figure are somewhat magnified in the following sketch:

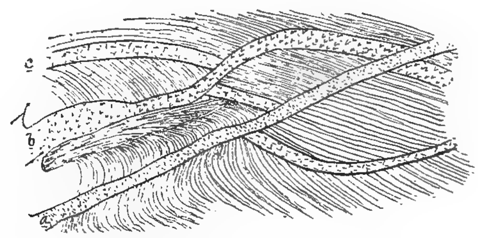

FIG. 31. CONSECUTIVE VEINS AT THE SAME PLACE AS SHOWN BY FIG. 30. BURNTSIDE LAKE.

a—Reddish, compact granulyte, with a little muscovite. *b*—Whitish granite, with abundance of biotite. *c*—Whitish biotite granite.

A remarkable convoluted vein of granulyte is represented by a literal drawing from the rock reproduced in figure 32. The bluff is here 50 feet high, more than half schist, interlaminated with granite. This convoluted vein continues fifteen feet. The volutions represented are included within the distance of four feet.

Trout lake lies north of Vermilion lake, and in many respects is a repetition of Burntside lake, as it embraces the transition line from the Coutchiching to the gneisses frequently called Laurentian. It is separated from Vermilion lake by a low range of hills which extends east and west, composed of mica schists and granite. The outlet stream from Trout lake descends by rapids and by a fall of a few feet near Vermilion lake, the whole descent being thirteen feet. The remains of an old water-wheel and stamp-mill erected at the time of the gold excitement of 1866 could still be seen at the falls in 1887.

The rock in the river channel is a mixture of mica and hornblende schist and gneiss. There are fine veins of red feldspar penetrating the rock in all directions. Most of the gneiss contains both orthoclase and plagioclase and more or less pyrites. The general strike seems to be east and west (Nos. 334H to 337H).

The point in the S. W. ¼ of N. W. ¼ sec. 19, T. 63-15, is composed almost wholly of mica schist. There are a few narrow veins or stringers of gneiss running through it in various directions, and one or two granite intrusions of considerable thickness. The mica schist here does not seem to contain any hornblende.

In the N. W. ¼ of N. W. ¼ sec. 19, T. 63-15, the rock is mostly a fine, gray, biotite gneiss, slightly porphyritic and containing irregular inclusions of mica schist (No. 338H). On the north side of the point at the same place the rock is syenyte gneiss in nearly flat beds (No. 340H). The schist with which it is bedded, and into which it graduates, is also hornblendic. The gneiss is pyritiferous. There is a heavy covering of drift here, and many boulders lie around.

In the S. E. ¼ of N. E. ¼ sec. 13, T. 63-16, there is an exposure 200 feet long of flat, bedded gneiss and mica schist. It is in bluffs fifteen feet to twenty feet high. The gneiss and schist grade into each other and alternate in beds of all thicknesses up to three feet. Most of it is fine-grained and more or less decomposed (No. 341H). These horizontal beds of gneiss and schist are cut by one or two nearly vertical granite intrusions (No. 342H). The feldspar in both the gneiss and granite is yellowish-white, and some of it is iron stained. They both contain more or less hornblende.

In the S. W. ¼ of S. W. ¼ sec. 13, T. 63-16, is a large, low exposure of gneiss and mica schist interbedded in vertical strata, and cut by vertical granite intrusions from an inch to four feet thick, running in all directions through and across the beds. Strike is E. 54° S. The schist is typical, biotite mica schist. The gneiss is fine-grained yellow rock, similar to most of that in this region. Following this along the shore in a southeasterly direction we soon come upon a perpendicular wall of rock with a smooth face twenty feet high and one hundred feet long. This looks like a wall of masonry made of thin slabs laid horizontally. On careful inspection it appears that most of the gneissic structure and the arrangement of the minerals in lines and bands is vertical, and the beds are laminæ or sheets instead of strata. In much of it there is no gneissic structure evident. In places the gneissic structure dips S. W. 45° This rock is hornblendic as well as micaceous and contains granitic veins (No. 343H). The direction of the face of this wall is E. 70° S., and the general direction of the gneissic vertical beds in it is about the same, some being however E. 40° S. At the edge of the water this appearance of laminæ disappears and the rock seems to be as usual in vertical strata. Quantities of boulders and pieces of the adjacent rock line the shores of this lake.

The rock on the point in the S. W. ¼ of S. E. ¼ sec. 14, T. 63-16, is gneiss and syenyte gneiss containing a little schist, both mica and hornblende. It seems to be in vertical strata. The syenyte gneiss contains rounded or lenticular lumps or nodules of actinolite mixed with a little mica. These nodules are four inches long, on an average, and vary from light grayish-green to greenish-black in color. They are much softer on the exterior than a short distance within. The hornblende on the exterior is altered to form some softer mineral (Nos. 345H and 345aH).

In the N. W. ¼ of S. E. ¼ sec. 14, T. 63-16, the shore rises up almost perpendicularly for forty feet. It is mica schist containing a little gneiss. It is all pervaded by more or less hornblende. The strata are much disturbed here, and have no permanent dip. The strike is E. 40° S.

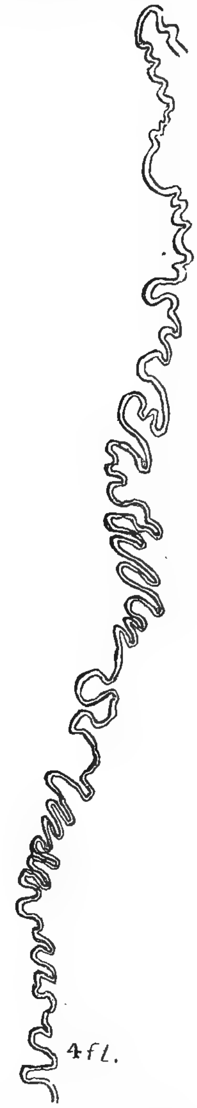

FIG. 32. CRUMPLED VEIN OF GRANULYTE AT THE SAME PLACE AS SHOWN BY FIG. 30. BURNTSIDE LAKE.

In the N. W. ¼ sec. 14, T. 63-16, the rock is principally a reddish biotite gneiss, some of it quite coarse and containing pyrite. It lies across the mica schist beds, which are vertical for the most part, but have been much distorted in places (No. 346H). This reddish gneiss is itself cut by thin, light yellow or white granite veins.

Red chlorite gneiss is found in the S. E. ¼ of S. W. ¼ sec. 15, T. 63-16. It occurs in vertical beds with strata of micaceous, hornblendic schist. Some of the beds are bent considerably and have a low dip to the north.

In the centre of sec. 15, T. 63-16, the bluffs rise sixty feet or more vertically or in overhanging masses. It is principally mica schist, with some gneiss and a few veins of pyritiferous quartz. The schist itself is gneissic and almost massive, it is in such thick beds. Where there is any bedding structure visible it is wavy and distorted.

Near the N. E. ¼ of S. E. ¼ sec. 10, T. 63-16, the granite shores rise forty feet above the lake in smooth, sloping ridges. Hornblende and a few other accessory minerals are present. In places the granite is quite coarse, orthoclase crystals four inches long being noticed. Some of it is pegmatitic. In some of this coarse granite the muscovite scales are set in or surrounded by quartz (Nos. 348H and 349H).

From here north the shores seem to be wholly granite, no schist being mixed with it. It is all decidedly acidic and does not contain much mica. The feldspar is orthoclase. It is jointed in various directions. Some-

times it seems to lie nearly flat, sheets of it lying over each other, dipping to the southeast. Granite from the S. E. $\frac{1}{4}$ sec. 11, T. 63–16, is No. 350H.

Syenyte is found in the N. E. $\frac{1}{4}$ of N. W. $\frac{1}{4}$ sec. 11, T. 63–16. It contains red orthoclase, dark hornblende, and but little quartz. Epidote is a common ingredient. It has much the same appearance and manner of occurrence as the granite. It is inclined to be porphyritic in places (No. 351H).

Across the bay in N. E. $\frac{1}{4}$ sec. 11, T. 63–16, the rock appears to lie in flat beds. It is gneiss, with about equal amounts of mica and hornblende. Some of it is almost schist, and some is granulyte. It is cut by intrusions of granite (No. 352H).

In the S. E. $\frac{1}{4}$ of N. E. $\frac{1}{4}$ sec. 11, T. 63–16, the rock is fine, gray, biotite gneiss, containing plagioclase feldspar. It is quite firm and solid, but contains mica schist beds and lumps in which the strata run nearly north and south (No. 353H). Portions of this same gneiss are very coarse, and the feldspar is orthoclase with the pegmatitic character.

Low, flat exposures of granite or gneiss are seen in the N. E. $\frac{1}{4}$ of sec. 2, T. 63–16. It is mostly fine-grained rock similar to No. 353H. It has bands of coarse granite running through it or lying on the surface. The line of contract or of separation from them is indistinct. Most of it has the appearance of being in beds dipping to the southeast at an angle of 30° or less. But in some of it there is an indistinct gneissoid structure which is about vertical. The shores are piled up for about ten or fifteen feet back from the lake, by the action of the elements, with masses of the subjacent rock and with boulders of granite. The gneiss contains a little hardened schist, and sometimes approaches the fineness of schist itself; but generally it is coarse, firm and compact.

Low exposures of porphyritic, micaceous gneiss are seen on the point in the N. W. $\frac{1}{4}$ of N. E. $\frac{1}{4}$ sec. 35, T. 64–16. In places it assumes the character of a breccia, and contains angular masses of hornblendic rock similar to that at the west side of Pelican lake.

Much fine pine grows around this lake. The water is clear and the lake shores and islands are beautiful. In many places, however, low reefs of rock extend out into the lake but a short distance below the surface of the water; thus making it difficult as well as dangerous for a canoe to land. In fact all of the shores have a very gradual slope into the lake.

A large exposure has been caused by fire in S. E. $\frac{1}{4}$ of S. W. $\frac{1}{4}$ sec. 26, T. 64–16. It is gneiss, partly fine and partly coarse. Part of it is mica schist and part half-way between schist and gneiss. Coarse masses of iron-stained quartz are seen here; also some coarse feldspar. In all this region there is a more or less striking appearance of horizontal lamination in the rock. In almost every place careful examination reveals the fact that the rock has a gneissic texture that is vertical or nearly so. Also when any schist beds lie in the gneiss they seem to be in vertical strata.

The point in the west half of N. W. $\frac{1}{4}$ sec. 30, T. 64–15, is composed of gneiss and mica schist rising about forty feet above the lake. At this place there is also a good display of the horizontal laminæ and vertical gneissic structure. The thin beds of schist which are in the gneiss are bent and doubled up like a letter *S*. The general strike is east and west.

There is a most enormous pile of "cobblestones" here. Just to the southeast of the long sand beach in the S. E. $\frac{1}{4}$ of S. E. $\frac{1}{4}$ sec. 24, T. 64–16, is a pile of them twenty feet or more in hight and extending for 200 or 300 paces along the shore. They are rounded and polished nicely and are from four inches to a foot in diameter.

At the north end of the lake the rock becomes more regular in its bedding and dip. The latter is north, at a high angle. At the very end it is mostly gneiss; but contains more schist or gneissic schist than the gneiss a mile or two south.

Coming south through secs. 30 and 31, T. 64–15, the beds of gneiss and schist gradually become more and more distorted and irregular. The dip gradually goes from vertical to horizontal, and the strike is extremely variable. The beds are about horizontal in the S. W. $\frac{1}{4}$ of N. E. $\frac{1}{4}$ sec. 31, T. 64–15. They are cut by vertical granite intrusions. In the N. E. $\frac{1}{4}$ sec. 32, T. 64–15, there is considerable mica schist, quite regularly interbedded with gneiss, having a strike E. 60° S.; dip N. 60°.

In general. This lake lies on an anticlinal. The flat-lying beds are in the middle or on the top of this anticlinal, and the strata dip north at the north end and south at the south end of the lake. The bays and general contour of the lake do not conform with the general strike of the formation, showing that the rock is very irregular in its bedding and dip.

Much hornblendic rock is seen on the west side of the lake and hardly any on the east side. The shores, as said above, are wretched for landing, large piles of boulders and loose masses of rock extending far out into the lake from nearly every part of the shore.

Long lake. The geology of this lake is quite different from that of Burntside lake, alongside of which it lies. Instead of firm mica schist or granitic shores, it lies in a basin of sericitic and chloritic schists, and of greenstones, which are exposed almost continuously along the shores. The northwestern shores, and the hill range adjacent which rises about 100 feet in sec. 20, T. 63–12, are conglomeratic. The general strike of the structures is a little north of east. The range of hills that rises on the north side of the lake at the east end, near the lake sinks away or divides in the promontory that shuts in the bay at the northwest end of the lake, but forms, in its continuation under the water, a series of islands. It seems to rise again on the south side of Burntside river, and to continue in the same direction. It is supposed to contain an unconformable line of contact on the Coutchiching and granitic rocks (metamorphic Lower Keewatin) described about Burntside lake. This line of nonconformity, after passing the west end of Burntside lake, runs southwestwardly toward the southern side of

Vermilion lake. Thus Long lake and Burntside lake together, geologically, span about the same interval as is covered by Vermilion lake.

At the western end of this lake are some rocks that resemble some seen at Kekequabic lake, these being the only two places known where this rock occurs in the state, viz., a fine-grained, felsitic rock, in which are disseminated hornblende crystals, a kind of hornblende porphyryte (No. 84W). This occurs on a little island N. W. ¼ S. W. ¼ sec. 29, T. 63–12. It is much sheared, and passes gradually into a sericitic schist in which these crystals are not found (No. 66W), and also, under favorable shearing, into a siliceous slate (No. 85W). Since these hornblendes are transverse to the schistose structure, frequently, they have apparently not been sheared, but may have been developed by the shearing process in a debris derived from a dioryte, viz., from Nos. 82W and 83W. This debris varies from very fine to coarse, and sometimes embraces fragments of quartz-porphyry and felsyte, being then quite suggestive of the horizon of the Stuntz conglomerate. Such a conglomerate, sheared, the fine debris converted into a sericitic schist, is represented by the following sketch made from the rock face N. W. ¼ S. W ¼ sec. 29, T. 63–12.

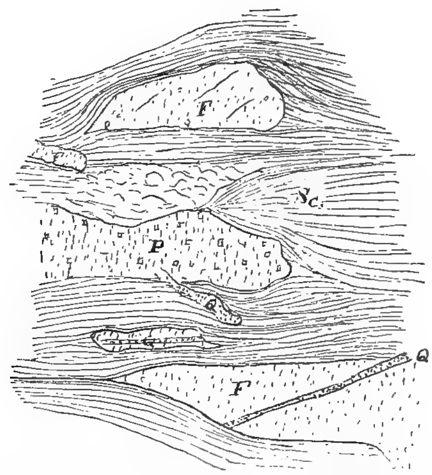

FIG. 33. PEBBLES OF QUARTZ PORPHYRY AND FELSYTE IN A FINE GREENISH MATRIX, SHEARED.
N. W. ¼ S. W. ¼ sec. 29, T. 63–12, on a small island. Long lake.

Sometimes the whole rock is evenly fine, or granular, and when sheared it gives a mottled sericitic schist, which crumbles in fine scales (No. 89W). When not sheared such rock is a firm grit, gray and brittle, a form of the "graywacke" of the region (No. 92W) in part, and when very fine it forms a flint, and, if sheared, a siliceous slate (No. 85W), and passes into argillyte. These forms grade together with the varying grain and dynamic action. These rocks occupy a small area at the west end of Long lake, and perhaps are all included in a sharp synclinal fold, originally non-conformable on the greenstone which lies on each side. (See the chapter on structural geology.)

Along the south shore in N. E. ¼ sec. 28, T. 63–12, and spreading largely inland toward Ely, and eastward, is a large and hilly display of greenstone (Nos. 91W, and 1002, 1003), which is a rather ambiguous rock. It is hard to separate, whether in the field or under the microscope, from the greenstone which is well known in the Archean (the Kawishiwin), and whose characters are represented by many rock samples. This greenstone range continues eastward and gives rise to the Kawasachong falls at the descent of the Kawishiwi river to Fall lake. It also forms the south shore of Fall lake westward from the mouth of Kawishiwi river. This is the formation which holds the iron ore at Tower and at Ely, notwithstanding the fragmental or crushed condition of the ore of the Chandler mine at Ely, causing it to resemble the "soft" ores of the Mesabi range. In numerous places on this hill range, banded jaspilyte, identical with that seen at Tower, is plainly exposed, especially in the next town east, where it is embraced in rocks Nos. 1014 and 1015 (sec. 30, T. 63–11). This rock belongs in the Archean, but non-conformably below the graywackes and argillytes and conglomerates of the southwestern end of Long lake.

The basin of Long lake lies therefore partly in the Upper Keewatin and partly in the Kawishiwin epoch of the Lower Keewatin. The Upper Keewatin is not known in this basin, eastward from the west end of Long lake, but the southern and northern rims approach each other at the east end of the lake and seem to shut it off. Indeed the whole of the north shore of the lake is composed of rocks of the lower Keewatin, consisting of greenstones, sometimes evidently of massive crystalline nature, and sometimes apparently of the nature of volcanic tuffs. They have everywhere been sheared and faulted, the original minerals lost, and the original structures replaced by an almost constant fibro-schistose structure, without evident sedimentary banding, which runs about east and west. They are much altered basic rock materials of some sort, and are frequently permeated by calcite, which is evident in a thin section, even in the most dense portions. In secs. 22 and 15, T. 63–12, are eruptives of later date, not sheared (No. 22H in part).

North of Long lake are hill-ranges running in a general direction N. 80° E., and increasing in hight toward the north, the upper level being at 190 feet above the lake. "In sections 22 and 15 these hills are made

up chiefly of a fine-grained compact green rock, firm and without appearance of any stratification or schistoes, structure (No. 22H); but there are curved lines or threads of schistose rock running all through it. The rock in these veins sometimes appears like dioryte (No. 21H), and sometimes like sericitic schist. There are crystals of hornblende in it that stand out on the weathered surface and give a darker and rougher appearance to the network of veins which is everywhere seen on the surface of the bare hills.

Through section 15 the hill-ranges are precipitous, and separated by deep ravines. The rock changes rapidly, becoming more massive and solid in structure toward the north. The hills nearest the lake are of a sort of greenish hydro-mica or chloritic schist. The next ranges are harder and less changed by weathering, and are finely crystalline in texture, like dioryte. The hills beyond these are coarser, and look like fine dioryte, and those still further north are still coarser and more crystalline. Quartz veins are common, running in all directions, and sometimes lying flat on the surface. The schistose rock seems to dip north, and sometimes contains irregular shaped fragments of the granular quartz, such as are seen in the schists north of Tower.

Portions of the rock in the first high range of hills north of the lake contain light-greenish spots, as if derived from an original amygdaloidal or fragmental structure. These stand out in little round globules on weathered surfaces (No. 26H).

The rock for the first three-quarters of a mile north of the lake, including the schists near the lake and the semi-crystalline rock further north, contains beds or veins of very hard, siliceous, flinty rock, which is like a petrosilex. This shows stratification, both on the surface, which weathers white, and in the greenish interior. Such beds stand vertical and extend for an indefinite distance east and west through the other rock. Their general thickness is about six inches, but some such are two and even three feet thick. An indistinct tendency to a rude crystallization is visible in this fine siliceous rock, as if it were homogeneous enough to crystallize like a mineral, the different parts being separated by straight planes, causing it to disintegrate in small angular blocks (No. 29H).

In making a traverse from Long lake to Burntside lake, in secs. 19 and 18, T. 63–12, a similar topography was encountered, combined with the same transitions in the character of the rock. The samples illustrative of this are numbered 2114 to 2123. The greenstone seen at the south gradually becomes re-crystalline, by the appearance of hornblendes, then of feldspars, and forms a dioritic rock. In places mica schist is associated, and sometimes mica schist and hornblende schist are irregularly intergraded and mingled. In going northward occasional small granitic dikes, often weathering red, are seen cutting the schists or more frequently running parallel with them. There is no transition to granite, but the two kinds of rock are continually distinct and separate. The greenstone with its modifications is plainly the older rock. At the shore of Burntside lake the rocks are wholly granitic.

Vermilion lake. This lake, with its attendant geology, embraces the most important elements in the contents of this chapter. In this place will be given only an outline of the geology. The most interesting questions, and the geology of the iron mines, will be found in the chapter devoted to the Vermilion lake plate (No. 86).

In the northwestern part is an oval-shaped area of granite and gneiss, surrounded by mica schist which dips in all directions away from the gneiss. Toward the north and west there is no known later rock, but toward the south and east these rocks are overlain by later strata consisting of graywackes, argillytes and conglomerates, these belonging to what may be separated from the rest of the Keewatin under the name of Upper Keewatin. The line of contact of these later rocks on the older is approximately represented on the accompanying plate, but it has not been detected with certainty except in the southern confines of the lake, and then the contact is not on mica schists and gneisses, but on the greenstone, quartz porphyry and iron ores of the vicinity of Tower, which are supposed to be of the same age (Lower Keewatin) as the mica schists of the northwestern part of the lake, the schists being crystallized by the proximity and activity of the granitic centres.

In classifying the oldest rocks, according to their relative ages, it is customary to assume that the bottom is toward the gneiss and the granite, but there is no certainty that the gneiss is at the bottom. On the contrary, there are good reasons to believe that the gneiss and the mica schists which accompany the gneiss, as well as the granite, are of later date, as rocks, than the greenstones that contain the iron ores at Tower. They seem to be only phases that have been superinduced on an older rock series. The mica schists certainly in some instances graduate into less crystalline rock, and quite evidently they are only changed condition of the more siliceous greenstones. If the gneiss or the granite prevails in any locality to the exclusion of the mica schist and other clastic rocks, it is perhaps owing to a locally more powerful metamorphism of the old series, represented in the first instance, and in its original condition, by the fragmental greenstones and their accompanying schists. Hence it seems quite reasonable to infer that the natural downward succession, in order of rock genesis, is toward the greenstones, and hence that the oldest known rock series in the state is the great greenstone series, which has been named Kawishiwin. This subject is further discussed in connection with the Vermilion lake plate,* and in the chapter devoted to structural geology.

There is a distinct line of non-conformity which marks the commencement of another series. This was not discovered until 1896, and it introduces an important new element in the classification of the oldest rocks which leads to a corresponding correction in all the reports that have preceded, wherever they treat of this subject. The basal rock at the bottom of the Upper Keewatin is what has been called, in the annual reports, the Stuntz conglomerate, from the fact that an island of that name in Stuntz bay consists largely of this conglom-

*As to the nature of the early differentiation into acid and basic rocks, and the nature of the first rock-crust of the earth, compare: N. H. WINCHELL. Some thoughts on eruptive rocks, with special reference to those of Minnesota. *Amer. Assoc. Adv. Sci.*, vol. xxvii, pp. 212–221, 1888; *Am. Geol.*, xxii, Nov. 1898.

erate. This graduates upward into quartzyte and to graywacke. The graywacke is seen to pass into finer and finer rock so as to constitute argillyte. The iron ores of the Vermilion range are in the older formation, and they have supplied debris to constitute a portion of this conglomerate. The non-conformity can be seen plainly in a small bay on the south side of the lake, on the west side of the bay, at the east side of sec. 20, T. 61–15, where a low knob of the conglomerate rises about fifteen feet above a surface of jaspilyte. This conglomerate consists, in the proportions of nine to one (in some places), of fragments from the jaspilyte, whereas it consists, at large, of felsyte and quartz-porphyry, with only rarely a fragment of jaspilyte. It is very evident here that the jaspilyte boss adjacent was the source from which the greater portion of jaspilyte pebbles were obtained. Compare the Vermilion lake plate. The Stuntz conglomerate extends east and west from this point, but its surface area has not been traced out in detail. Indeed, it is not possible to delineate with correctness the area of the Upper Keewatin, and the accompanying plate shows simply the Keewatin, in which are included the Kawishiwin and the Upper Keewatin. At other points the Stuntz conglomerate varies to a greenish conglomerate with fewer siliceous pebbles, as mentioned at Long lake.

The region between Vermilion and White Iron lakes. From the greenstone and jaspilyte ridges at Soudan to the granitic rock about White Iron lake in general the country is occupied by an ambiguous greenstone, and by mica schist, and granite. The accompanying plate shows approximately the northern extension of the last mentioned rock. As in many other places, the change from the mica schist to greenstone is one of gradual transition, but it cannot be stated, as yet, what amount of this greenstone belongs to the Lower and what to the Upper Keewatin. Suffice it to say here that in some of this greenstone the jaspilyte bands are embraced. This is considered Archean, and is put in the Lower Keewatin. Intimately associated with this is more or less plainly fragmental greenstone, which, having been sheared and compressed, has frequently been converted into a green schist, which is very similar to the green schists of the Archean. Such are found about Ely and along the railroad westward, frequently exposed freshly by the rock cuts. It is seen about the southern confines of Eagle Nest lakes. It is made up sometimes very largely of rounded masses, as if it were originally a conglomerate, or an agglomerate. This feature is conspicuous at the railroad cuts between Tower and Ely. Whether it is the basal member of an unconformable overlying formation, and equivalent in age to the Stuntz conglomerate of the Upper Keewatin, or is a portion of the greenstone proper of the Lower Keewatin, it has not been possible to determine, but recent reëxaminations indicate that it is a part of the Lower Keewatin. The determination of this involves the question of the age of the Giant's range granite, and also the relation of the Upper Keewatin to the Animikie. For instance, the Giant's range granite is the focal point, in a dynamic sense, on which depend the mica schists which lie alongside of the granite. The mica schists, according to numerous observations, are a crystalline condition of the fragmental greenstones and graywackes, into which they graduate conformably, and if this fragmental greenstone is Upper Keewatin, the epoch of the Giant's range granite separates the Upper Keewatin from the Animikie, and the non-conformity which exists at Tower between these greenstones and conglomerates (as the Stuntz conglomerate) and the jaspilyte, and its cotemporary greenstones, is not cotemporary with that which exists below the Animikie along the south side of the Giant's range. If, on the other hand, these extended fragmental greenstones belong in the Lower Keewatin, with the jaspilyte, as has been generally considered, it is difficult to find how they can be separated from Upper Keewatin graywacke-greenstones, either petrographically or structurally, and the chronological relation of the Animikie to the Upper Keewatin is not determined by the age of the granite of the Giant's range.

Leaving this question for the present it will only be necessary here to give some of the details of the field observations in the region here considered, so far as they lie outside of the area of the Vermilion Lake plate.

Southward from Mud creek the country is crossed in a southeast direction by an interrupted succession of ridges of greenstone and green schist, separated by narrow valleys. In this region are several known exposures of the jaspilyte, or iron ore, similar in character to that in the ridges at Soudan, and in several places considerable mining has been done, of an exploratory kind, but as yet no large body of merchantable ore has been discovered. Such portions of the greenstones or graywackes as embrace jaspilyte beds are probably assignable to the Lower Keewatin, and such portions as contain isolated angular pieces of it are to be considered as in the Upper Keewatin.

There is also in this region, in T. 62–14, a considerable amount of sericitic schist, which is a rather indefinite term, as generally employed. If the term be restricted to sheared quartz porphyry, or a sheared debris of quartz porphyry, it will be found that both sources for such rock are found in the region southeastward from Mud creek, but the more common source is a sheared debris of quartz porphyry or of greenwacke. There seems to have been in the Lower Keewatin, along with the jaspilyte and the enclosing greenstones, a large amount of quartz porphyry, although it has been certainly identified in but very few places. If the term sericitic schist be allowed to cover some of the graywackes when sheared and some of the indefinite schists that are phases of chloritic schist, there will be found to be a large amount of that rock in the region between Vermilion lake and White Iron lake.

Quartz porphyry at Ely. Toward White Iron lake the graywackes and green schists are changed to mica-hornblende schists, and when they embrace jaspilyte such jaspilyte is blackened, the hematite being changed to magnetite.* Along the northwest side of this lake these schists are cut by granite dikes with greater and greater frequency going toward the main granite area, and with less and less effect on the schists going away from it. The most remote irruptive rock of this kind, known in this vicinity, exists amongst the bouldery

*Compare N. H. and H. V. WINCHELL. Bulletin No. vi, pp. 12–23.

FIG. 1. THE AGGLOMERATE IN GREENSTONE AT ELY. (p. 255.)

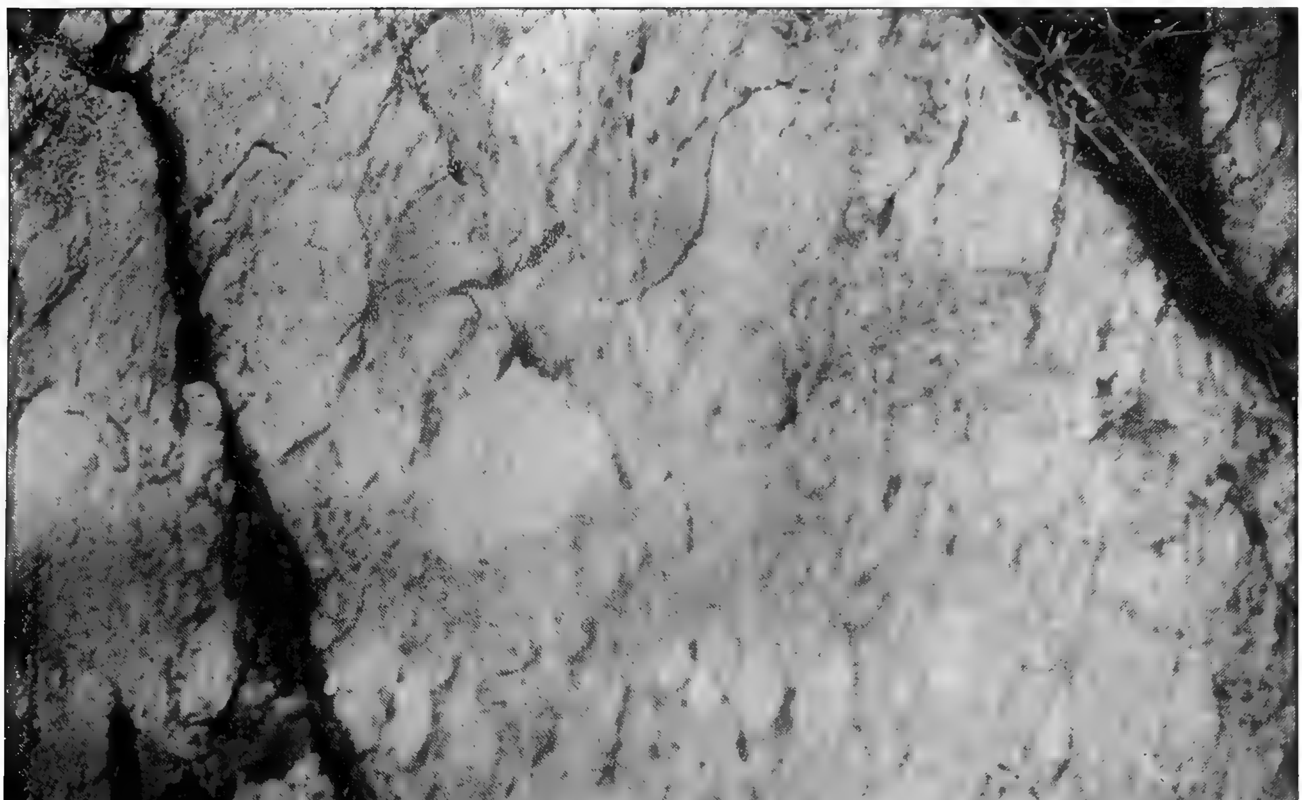

FIG. 2. CONGLOMERATE AT THE BASE OF THE UPPER KEEWATIN, ON A SMALL ISLAND IN LONG LAKE, SEC. 29, 63-12. (p. 257.)

greenstones about three-quarters of a mile west of Ely (No. 1789). There is, however, no evidence that this is of the age of the granitic intrusions at the northwest side of White Iron lake. Petrographically it is allied to some dikes that cut the greenstones on the Kawishiwi river, viz.: Nos. 416G, 417G, and 500G, and these are all so different from the Giant's range granitic mass that they cannot be considered, safely, as being apophyses from that mass. They are more likely to be of an earlier irruptive epoch. Contact rocks of the White Iron lake area of granite on the schists of the vicinity are Nos. 1117–1122. They are fine-grained but holo-crystalline and fresh, while the rock (No. 1789) is fine-grained, though porphyritic and much altered, having an alliance with the quartz porphyries and felsytes, which are associated with the greenstones, and which are seen as pebbles in the Stuntz conglomerate, and probably of the same date as those quartz porphyries.

The acid porphyritic rock (No. 2095) here referred to is to be seen about three-fourths of a mile west from the Ely railroad station, on the conspicuous hills west of the creek and north and northwest from the cemetery. It appears irregularly in the country greenstone, but can be traced about a quarter of a mile, running about N. 30° E. It occupies a position and direction as if it entered openings along the jointage of the greenstone, in a coarse alternation with belts of the greenstone. In one place a small patch of the porphyry is detached, and is now embraced wholly in the greenstone, free from the rest, running down into a narrow crevice. This suggests that the greenstone is later, and involved the porphyry. On the other hand bits of the greenstone are involved in the porphyry transverse to the structure of the porphyry, instead of coincident with it, and also transverse to the structure of the greenstone, indicating strongly that the greenstone pieces have been derived from the greenstone on the intrusion of the granitic porphyry. And it is perhaps more probable still that neither of these rocks here acts as an intrusive on the other, but that the folding and truncation of the folds which the rocks have suffered, along with shearing, have brought them into contact. Similar phenomena are exhibited on the "burnt forties" near Tower, as described in the chapter on the Vermilion lake plate. Near Ely the porphyry is traceable for about fifty rods, appearing like a dike about twenty feet wide (or sometimes wider), running about N. 30° E. It both encloses and is enclosed by the adjoining greenstone. Its width varies from fifteen feet to fifty feet, and its course swings a little north and south. It runs out toward the east in a series of isolated white spots in the greenstone, which can be traced, with interruptions for thirty rods further. This action is much like the squeezing out of a fold which embraced a lot of quartz porphyry, followed by the truncation of both rocks by an irregular horizontal plane. Another appearance of what may be the same mass is near the centre of sec. 32, T. 63–12 (No. 2107). There is an extended range of granite with a quartz vein fifty feet or more in width, both running parallel with this, in S. W. ¼ sec. 30, T. 63–12.

The greenstones at Ely. The greenstone formation, as seen at Ely, is a much altered and very ancient rock. It presents the same indefinite characters as elsewhere. Some of it is evidently fragmental, and some is irruptive, if not eruptive and effusive. Some years ago the writer described the rock seen in a small cut a few rods west of the depot at Ely* as a volcanic agglomerate, and since then this rock-cut has been reëxamined and photographed. It is represented by plate U, figure 2, and plate V, figure 1. The rounded parts of which the rock almost wholly consists (No. 1510) are shown in these plates, but the darker green schist which surrounds them is not well indicated. The scale of darker schist is about half an inch thick, but it frequently forms considerably larger areas of irregular shape, and is also sometimes much coarser than the grain seen in the interiors of the rounded masses. It is apt to be the collecting place of calcite, "chalcedonic" silica, and of cubes of pyrite. The rounded masses are themselves divisible into an interior part (No. 1510), and a curiously amygdaloidal periphyry (No. 1511). In the latter the substance of the rock is penetrated by tubes or pipe-like amygdaloidal passages in which now is found a filling either of calcite or of chalcedonic silica. These tubes stand perpendicular to the surfaces of the rounded masses, and are separated, on an average, about half an inch from their neighbors. They are not everywhere present, but they are so abundant as to make a marked distinction between the interior and the exterior of the masses. They are sometimes more than an inch in length, but most frequently are less than an inch. They do not enter, or but slightly, into the darker green schist, which is wrapped about the masses with its fibrous direction parallel to their surfaces. They are approximately circular or pipe-like, with a diameter of about two millimetres. Some of them, however, are a little zigzag, and roughened on their inner surfaces. This is revealed by fractures across them after the calcite has weathered out, which is the case in many instances. While these tubes are generally simple, and approximately round in section, they are not always so, but they flatten out for a short space and return again to pipe-stem shape, and sometimes they branch, or coalesce.

In other places about lake Superior similar rounded masses have been noted in what is apparently the same greenstone, and they have been attributed to a crushing and shearing action exerted by dynamic forces upon a greenstone which was originally massive and crystalline.† But there are difficulties which seem to be at present insurmountable which oppose this explanation, and they have been presented by the writer‡ in a former report. While, however, the subject will not be discussed here at length,§ and although it may be admitted that some difficulties attend all theories of the origin of the greenstones, it will here suffice to state that in the

*N. H. WINCHELL. The Kawishiwin agglomerate at Ely, Minn. *American Geologist*, vol. ix, pp. 359–368, 1892.

†GEORGE H. WILLIAMS. The greenstone schist areas of the Menominee and Marquette regions of Michigan. *Bulletin No. 62*, U. S. Geol. Survey, 1890, pp. 137, 166, 203; see also p. 177.

F. L. RANSOME. Eruptive rocks of Point Bonita, Cal., *Bulletin, Dept. Geol.*, Univ. Cal., vol. i, pp. 71–114, 1893.

‡N. H. WINCHELL. The origin of the Archean greenstones. *Twenty-third Annual Report*, pp. 4–35, 1894. The origin of spheroidal Basalt, *American Geologist*, vol. xiv, pp. 321–326, 1894.

§The reader will find further consideration of the greenstones and their origin in the chapter devoted to the petrographic geology of the northern part of the state, as well as in that devoted to structural geology, vol. v.

opinion of the writer they are largely of pyro-clastic origin; that is to say, the materials of which they are composed had origin in volcanic action, and that, whether tuffs, bombs, ash or liquid lava, they generally came into contact at once with the Archean ocean, and were by it greatly altered, chemically and mechanically, often reduced to a volcanic pulp, and generally distributed and often characteristically stratified by its waves and currents. In most cases they have suffered by stresses of dynamic action, and, being probably the oldest rocks of the earth's crust, they have, as a group, been longest subjected to all the disintegrating action of atmospheric and other agents.

These ovoid and spheroidal masses are a peculiar feature of this great greenstone, which has been seen in numerous places within the area of this plate, and particularly toward the west from Ely; and their nature and origin are problematical. They are described in thin section, microscopically, under the rock Nos. 1510 and 1511. Compare also rocks Nos. 1786 and 1788.

There is at Ely a difference noticeable in this greenstone, between evidently massive dikes of original diabase and the chief mass of the greenstone. A branching dike or bleb of irruptive greenstone (No. 1786) is seen crossing the town site from northeast to southwest, appearing best on the very summit of the hill on which, in general, Ely is situated. Its outlines cannot be traced exactly because of earth-covering, but it is at least ten or fifteen feet wide, varying in direction as well as in dimension. Its contact with the siliceous and bouldery greenstone is exposed on the street near the Catholic church. This trap dike is homogeneous in color and grain. It is so altered that hornblende is its principal ferromagnesian mineral, and the feldspars are crowded with microscopic mineralizations of secondary origin. The dike separates so as to embrace parts of the greenstone, and it also encloses smaller pieces. It presents a noticeable contrast with the greenstone, which here is very coarsely and abundantly bouldery or agglomeratic.

West from the depot, where this bouldery structure appears at the little cut already mentioned, a similar but finer greenstone spreads widely (No. 1788), and appears in other low knobs. This also has an eruptive aspect (at least outwardly) and a resemblance to the rock No. 1786, in patches. This rock, as it is followed along toward the "Lockhart" property, loses some of its evidently igneous characters. It has siliceous and epidotic (?) rounded and also angular grains, and, though apparently massive, there is an appearance of fragmental characters. It then terminates toward the west by abutting on a bouldery patch, in which the grain and substance of the massive (?) rock becomes finer, and then enters among the bombs and surrounds them, forming the dark green coating which envelops them as described at the rock-cut. A careful discrimination of the microscopic characters of the rocks (Nos. 1786 and 1788) here has an important bearing on their possible difference of origin, and hence on the origin of the ambiguous greenstone in general.

The rock No. 1786 is plainly an intrusive basic rock of very old date. This is apparent by its appearance in the field. Microscopically its characters indicate a much altered diabase. The pyroxene is nearly obliterated —indeed the section examined has only one grain that seems to be a skeleton of an old idiomorphic (?) pyroxene. Throughout the skeletal remnant, coincident with partings which were probably at first the diallagic cleavage, epidote has been generated and now lies in bands which extinguish in consonance, the intervening bands being composed of secondary feldspar which extinguishes in part in consonance with larger feldspars that lie outside, and of calcite, while near the centre is an area that is nearly dark constantly between the nicols. The conspicuous ferromagnesium mineral is hornblende, which is in elongated, small crystals whose cross sections are nearly perfect rhombs, occasionally composed of two individuals, with sharp and perfect prismatic cleavages and straight, prismatic outlines, but whose sections, cut parallel to the vertical axis, show the ends of the crystal as fibrous terminations without definite boundaries. These hornblendes have had two periods of growth, the last one being evinced by a colorless fringe about some of the cross sections of the otherwise brown crystals, the fringe extinguishing with the body of the crystal. They are also irregularly intergrown and twinned, and they penetrate the boundaries of the secondary feldspars.

The secondary feldspars are much like quartz, and can hardly be discovered to possess any cleavage. Quartz is also present, as well as calcite. The former has developed so as to embrace both epidote and hornblende. The old feldspars are clouded with chlorite and other obscurities, and can barely be said to show still the albite twinning. They embrace both hornblende and epidote. There are spicules which appear to be apatite, and many highly refractive small grains of irregular shapes scattered about the section which are perhaps not epidote.

The whole rock has been recrystallized, and quartz and calcite have entered it from without. Yet, it is a holocrystalline rock, and its minerals are evident both as to shapes and optic characters, the hornblende being porphyritic.

The rock No. 1788 is quite different, although when collected it was supposed to be similar to No. 1786, and as No. 1786 demonstrates by its dike-like action that it is an igneous rock, it was considered that No. 1788 might also be igneous. On making microscopic examination, however, they seem not to be so allied. Rock No. 1788 is much more decayed, showing a considerable amount of calcite. It contains no porphyritic hornblendes, but a fine and often fibrous actinolite, or other amphibole, is abundant, especially in the areas of the old pyroxenes. There is also a wide distribution of small irregular grains of epidote like those mentioned in the description of No. 1786. There are multitudes of little feldspars, much smaller than in No. 1786, and there are remnants of old feldspars now mostly occupied by a micro-granulitic mass of fresh feldspar grains, the original orientation being sufficiently preserved, in some cases, to show the change that has taken place. A small amount of quartz can be seen to surround, occasionally, the small epidotes. The rock as a whole is quite similar to much that is included under the term greenstone.

In going carefully over some greenstone knobs west from the Catholic church at Ely, a patch of greenstone breccia (No. 2092) appears in the interstices between the agglomeratic shapes, cemented by calcite. The fragments are numerous and angular, averaging perhaps one-fourth or one-half inch. Such an appearance suggests the idea of a flow-breccia, on dry land, as the possible cause of the agglomeratic structure, rather than the hypothesis of bomb-projection by volcanoes and deposition in water. It is to be noted also that sometimes the agglomeratic forms are large and of irregular shapes, and their outlines do not apparently unite so as to enclose isolated individual masses. This constitutes a difficulty in the application of the bomb hypothesis. The periphery of the bombs is not always amygdaloidal (No. 2093), but is sometimes finely specked with a white-weathering mineral in round spots as large as a pin-head. These pellets are finely granular, siliceous and gray. They multiply and coalesce toward the centre, forming the mass of the interior. This belt is, in general, outside of a coarsely cavernous belt which is frequently interrupted (or wanting), and which is apparently the representative of the pipe-like amygdaloidal structure.

North from Ely, near the lake, is a low knob of jaspilyte, showing the greenstone contorted with the jaspilyte. This also shows places where the greenstone element is originally mingled with the jaspilyte, and *vice versa*, but for the most part they are distinct.

Westward from this point, but before reaching the boat-house, a gradual change comes over the rock, which becomes lighter-colored and more siliceous, resembling a very fine graywacke. It contains not only rounded, but angular, bits of rock not much unlike the rest, embraced in the general mass (No. 2094), suggesting the structure of a breccia formed by pressure and shearing, from a stratified slate and fine graywacke. This rock is very fine, like felsyte, but is not porphyritic.

West end of Long lake. On the blunt, large point of land, S. E. ¼ sec. 29, T. 63–12, may be seen an alternation of soft argillitic slates, fine and slippery (No. 2097), with others that are coarser grained (No. 2098), whose strike is about N. 45° E. The coarser rock appears to be the result of wastage from a rock like the white rock (No. 2095), much pressed and sheared. On the little island, briefly described in the fifteenth annual report,* S. W. ¼ sec. 29, is a form of the Stuntz conglomerate. The matrix is greenish and rather coarse (No. 2099), containing minute hornblendes (?), and the pebbles are of different kinds, viz.: (1) Mostly of rock like No. 2095, sometimes containing a few quartz grains, making a quartz porphyry varying to (2) A non-quartziferous felsyte; (3) Quartz, but few pebbles seen; (4) Greenstone; (5) Hornblende porphyry (No. 84W). This conglomerate gives place rather suddenly to argillyte toward the south, yet the transition is marked by a distribution of pebbles for a few inches into the argillyte. It is therefore a true sedimentary transition. The argillyte runs in agreement still further east on the blunt point, and parallel to this sedimentary contact, the dip being 80° toward the southeast, the conglomerate being on the northwest side of the island. Hence, in general it is legitimate to infer that about Long lake this schistose and slaty structure shows the direction of the bedding upon which it has been superimposed. This conglomerate is evidently the basal part of the Upper Keewatin. A photograph made here is reproduced in plate V, figure 2.

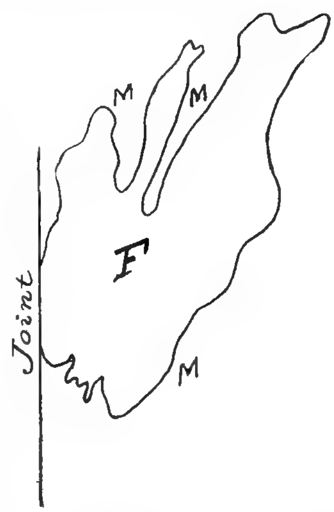

FIG. 34. DISTORTED PEBBLE IN THE BASAL CONGLOMERATE OF THE UPPER KEEWATIN.

This rock has been much sheared, and the pebbles all lie elongated in the direction of the schistosity. Some of them have been partly separated or folded on themselves, showing re-entrant angles as they are exposed to the weathered surface, into which the materials of the matrix have been crowded. One of the most perfect exhibitions of this distortion, sketched from this rock, is shown by figure 34. This shows plainly that when we know that we have to do with a conglomerate, such changes of form have taken place, and re-entrant loops formed by shearing. Such irregularity of form is common in the bouldery greenstone, and has sometimes been an obstacle to the idea of fragmental accumulation.

From this island, toward the southwest, is a bluff on the mainland, consisting of a fine and siliceous greenstone (No. 2101) or greenwacke. It is firm and siliceous, but on the bald, weathered cliff it cannot be distinguished easily, if at all, from the agglomerate-conglomerate of the greenstone. There are no bouldery masses with amygdaloidal peripheries, but the rock is rough, and in places very fine-grained, resembling the fine graywackes, such rock running in belts of a few inches in width, suggesting the argillitic aspects of the island. On freshly opened jointage planes, as formed by slides at the shore, this rock presents a striking aspect; it appears to be a coarse fragmental, either a conglomerate or breccia, probably the latter. Some of the evident pieces are eight to ten inches in longer diameter, but do not differ essentially from the surrounding rock. It indicates great dynamic fracturing and pressure.

Rising in the midst of this is a small area of apparently crystalline granitic rock (No. 2102), perhaps a form of No. 2095, but not porphyritic, though quartzose, which can be traced only about a rod. Its position here is also perhaps due to dynamic fracture and displacement.

Other islands, further north, are also elongated with the strike of the formation, although composed of an indefinite greenstone and presenting a similar brecciated exterior. A high greenstone range (No. 2103) appears in N. E. ¼ S. E. ¼ sec. 30, T. 63–12, opposite the foregoing islands at the shore.

*A. WINCHELL. *Fifteenth Annual Report*, pp. 53–54.

A small island, near the point N. W. ¼ S. W. ¼ sec. 29, T. 63-12, consists of a gray subcrystalline rock (No. 2104), a condition of the prevalent greenstone of the region, but lying too far north to belong to the main high range. In outward appearance this approximates gabbro, but is probably a dioryte. Schists, sericitic and flinty, occupy the lake shore westward from this island (Nos. 2105, 2106).

The celebrated location on sec. 30, T. 63-11, shows much jaspilyte exposure, forming a general belt about east and west. This belt is composed of interrupted abrupt ridges which have an east-northeast direction. The surrounding greenstone is somewhat agglomeratic, but not conspicuously so. The ore is not brecciated, as at Ely, but massive, as at Tower. The hematite forms a secondary cementing material for a breccia of red and brown jaspilyte. The jaspilyte itself is earlier than the ore, and was much shattered. On the other hand, at Ely the ore is the jaspilyte breccia, and at Tower the ore is the jaspilyte. This may indicate two epochs of ore formation in these jaspilyte masses.

The high ridge which lies immediately south of the town site of Ely consists apparently entirely of greenstone with many spots and nodules and pseudo-veins of epidotic rock (No. 2113). It is often very fine-grained and siliceous, but not distinctly bouldery. The ridge descends to a great rocky valley toward the south which has another similar ridge on the south.

West from Long lake, but south from the quartz vein described below, are large ridges of greenstone running nearly east and west. At the N. E. ¼ S. E. ¼ sec. 36, T. 63-13, this rock has an outer weathered surface blotched by original subangular forms (No. 2125), the difference in color being due largely to variation in the frequency of the hornblendes, which are large and conspicuous, both in the boulders and in the matrix. On the north side of this ridge is argillyte, nearly vertical, but dipping to the southeast so as to pass under the main ridge. The matrix of these sub-angular masses is rather homogeneous and apparently a sheared igneous rock of dioritic character (plate W, figures 1 and 2).

At the extreme northeast corner of sec. 36, T. 63-13, is a belt of jaspilyte, traceable for about a mile. This jaspilyte blends with the country rock, producing an intermediate phase, a siliceous greenstone (No. 2126). At this place the whole formation has that irregularity which has been called frequently bouldery, *i. e.*, it is blotched in the same way, and the grayish and greenish jaspilitic silica surrounds the masses.

Auriferous quartz vein. At the west end of Long lake, S. W. ¼ S. W. ¼ sec. 30, T. 63-12, is a conspicuous display of quartz and granite, the former carrying gold. An average sample selected from the dump, assayed by F. F. Sharpless, gave $8.64. Some casual working has been done on this vein, and numerous assays show, according to the statement of Mr. McIntosh, one of the owners, an average of over $10.00 per ton. The vein is traceable about an eighth of a mile, a little north of east, with an irregular width reaching a maximum of about eighty feet. It accompanies a granite dike. The ore is not abundant, but is in irregular streaks in the quartz.

Traverse from the green schists to the granite, etc. At the northwest corner of Long lake a traverse was made due north to Burntside lake for the purpose of observing the manner of transition from the green schists and argillytes to the crystalline schists and granites seen at Burntside lake. The region is largely moss and timber-covered, rendering it impossible to observe the exact relations of the changing rock.

Along the shore of the lake, north from the mouth of the river, and on some small islands, can be noted a change coming on gradually in the aspect of the rock. It has a rigidness and a long, fibro-lamellar structure, though still green. At the point of leaving Long lake the rock is a greenish, more firm, sub-crystalline condition of the same rock (No. 2114). At about thirty rods from the lake, and forty or fifty feet above it, the rock is more coarsely crystalline, with hornblendic crystals (No. 2115). At eight rods further north it is finely porphyritic, with feldspar in spots, and in places it weathers red (No. 2116). At eight rods further north is a compact, dark green rock, not plainly crystalline (No. 2117). At nine rods further north, the rock is much like the last, but coarser and somewhat crystalline (No. 2118). At nine rods still further north, just at the southern brow of the main hill, the rock is very tough, lighter weathering, showing a phase of the regional metamorphism of the greenstone—a crystalline rock, light green in color, a dioryte (No. 2119). At the top of the same hill, about 200 feet above the lake, the rock is somewhat coarser, but otherwise like the last (No. 2120). Nos. 2119 and 2120 are quite similar to rock No. 2104, which constitutes a small island in the lake at the western end, noted above. At one-half mile from Long lake a dike of reddish granite (No. 2121) two inches wide is encountered on pulling off the moss, running with the structure about east and west. The country rock is somewhat micaceous. At twenty rods still further north the country rock is a coarse hornblende schist (No. 2122). At the top of the hill south from Burntside lake, at 100 feet (±) above that lake, and perhaps fifteen rods from it, the underlying rock is mica and hornblende schist (No. 2123), these minerals irregularly alternating in a schistose manner. This occurs after passing considerable granite. At the south shore of Burntside lake is granite (No. 2124).

This traverse affords a very interesting section. It shows the greenstone changing gradually, under regional metamorphism, to a hornblendic rock or dioryte, which is in places micaceous. There is also, at the points observed, a mica-schist foliation parallel with the known sedimentary structure, a fact which has been verified at other places where the original sedimentary banding was evident.

There is, for the most part, a rather abrupt transition from the Keewatin in this area to the eruptive granite of White Iron lake. The belt of mica schist which usually separates them is narrow and not conspicuous. It is only known about the north end of White Iron lake. It is supposed to extend westwardly for a few miles, as represented on the plate, and may be much larger than is shown.. There is, besides, a more or less interrupted patch or belt of mica schists, not represented on the plate, which extends rather irregularly about the west and northwest environs of Birch lake, illustrated by rock Nos. 958 and 958A. This schist is greatly affected by intrusions of basic as well as acid rock, and occurs frequently as isolated bunches, sometimes of small size, but closely

FIG. 1. ANGULAR MASSES OF GRANITIC ROCK EMBRACED IN HORNBLENDE PORPHYRYTE? (2125) THREE MILES WEST OF ELY. (p. 258.)

FIG. 2. SAME AS FIG. 1, NEARER VIEW. (p. 258.)
[COMPARE FIG. 2, PLATE Z.]

grouped, surrounded by granitic rock. Very much of the dark mineral which gives character to the rocks about the west end of Birch lake is hornblende (Nos. 971–975), and the rock here is to be considered a phase of the massive rather than of the schistose portion of the Kawishiwin.

White Iron lake. At the rapids, at the outlet of White Iron lake, a siliceous mica schist, cut at the lake level by an east and west dike, contains magnetic jaspilyte, the structure standing nearly vertical, and the rock contains garnets as well as pyrite. This ferriferous belt extends both eastward and westward. It appears on Garden lake, and is perhaps the same that extends through sec. 30, T. 63–11, and to Ely, where it furnishes the iron of several mines. At the same time there are known exposures of jaspilyte further south, some of them not far from the northern limit of the granite in T. 62–12. Indeed, the rather fortuitous distribution of the deposits of iron ore in the greenstones and in their derivatives, the mica schists, makes it impossible to trace them far, and rather impels to the idea that they cannot be stratigraphically collated, *inter se*, and that the only grouping that can be warrantably offered is to state simply that they are scattered through the Kawishiwin Archean, without observable order.

The syenyte along the west side of White Iron lake, in sec. 6, T. 62–11, is represented by No. 952, which is coarse, weathers red, in massive domes, like an irruptive rock, and on the east side of the lake (about centre of sec. 12, T. 62–12) is in contact with an old basic irruptive (Nos. 1128, 1131), similar to that mentioned at the northwest end of Birch lake. Such intrusion of this acid rock into dark hornblendic rock is common along the west side of White Iron lake and north of Long lake. It is possible that this hornblendic massive rock is only the contact phase of the greenstone. Indeed, its relation to the granitic rock of the region is the same as that of the greenstone to the granite. The greenstone in general is the oldest rock known in the region, or in the state. But whether the fragmental part or the distinctly massive is the older, there is as yet no warrant other than hypothesis for saying. Of course, the dikes that cut the greenish graywacke, as at Ely (No. 1186), are younger, but these dikes are not known to be of the age of the great greenstone of the Kawishiwin.

Birch lake and vicinity. The shores of Birch lake are partly in the gabbro and partly in granite. On the east side of Birch lake, about N. W. ¼ of sec. 20, T. 61–11, is a perpendicular bluff of coarse gabbro, rising about thirty-two feet above the lake, having large rhomboidal fallen masses lying at the foot. It faces west, and shows on the perpendicular wall a coarse-bedded structure, brought out by the grooves that run across the wall produced by unequal weathering. These dip toward the south at an angle of forty degrees from the horizon, the large grooves being from three to five feet apart, but sometimes having more frequent finer ones between them.

These grooves are due to the weathering out of a mineral which happens to have been more abundant in these lines, compared to the other minerals, than in the rest of the rock. This same mineral is found throughout the rest of the rock, though not arranged in gneissic order, and its more rapid disintegration causes numerous small pits over the weathered surface. On making examination of this rock in thin section (rock No. 954) it presents a beautiful illustration of an olivine gabbro with biotite. The apparent bedded structure of the face of the cliff is caused by the more rapid decay of the olivine, which lies in greater abundance along certain lines.

At about the section line between secs. 29 and 30, T. 61–11, on the south shore, is another perpendicular bluff of gabbro. Indeed, numerous nearly perpendicular bluffs, from thirty to fifty feet high, made of this rock, appear at the shore through section 30, while on the north shore they are gradually ascending from the water level. This is owing to the prevalent dip of the main structural planes of the gabbro being toward the south, or southeasterly.

A curious fact is the quick change in the character of the boulders, as the character of the underlying rock changes. In the syenyte region they are mainly of syenyte, but where the gabbro begins they immediately become almost wholly of gabbro. The decaying olivine gives a pitted surface to nearly all of the boulders.

Some of the syenyte (or granite) seen in boulders in sec. 26, T. 61–12, has the appearance of gneissic structure, suggesting that part of it may have been derived from metamorphism of sedimentary rocks (No. 955). It is dark-colored, the crystals are imperfectly formed, and crowded, and much finer than in the syenyte mentioned seen at White Iron lake. Other parts (seen in boulders in section 26) are chloritic and dark-colored (No. 956), and some slabs appear like a micaceous quartzyte, but may be a somewhat changed olivine rock (No. 957).

The little point on the north shore, situated in the N. E. ¼ of the S. E. ¼ of sec. 21, T. 61–12, consisting of a breccia of mica schist cemented by granite (No. 958), shows the manner of contact. The granite goes generally in all directions, embracing the mica schist, and also appears as isolated masses. It also runs parallel to the schistose structure, producing a bedded gneiss, which dips about west 75° from the horizon. This is the same as the mica schist and interbedded granite seen on the north side of Vermilion lake. No. 958A shows some of this mica schist, while No. 958B shows the nature of a narrow vein or "dike" of the granite, and the full width of it (about one-fourth of an inch), beyond which it continues, but gradually diminishes to a needle point, and vanishes in the schist. It is hard to understand how a true igneous dike could thus fade out. It seems to disappear because the mica gradually prevails over the other minerals and converts it into mica schist, which itself seems to contain only the minerals seen in the granite.

Through the western part of sec. 22, T. 61–12, on the north shore, only the igneous looking, coarse-jointed syenyte can be seen. It is coarsely crystalline, has a bedding structure similar to what can be seen in the trap-rocks of lake Superior, but in the eastern part of the section a fine-grained, red-weathering bedded granite appears, both near the shore and also in a bluff at some rods from the shore. The bluff that faces the lake has the appearance of being an old wall of masonry, the rough, thin layering appearing about as distinct as the courses in a rubble wall when pointed with mortar by the mason and smoothed by the trowel. The beds are from four to eight inches thick, and dip easterly about 5° from the horizon. This granite, which is fine-grained

and micaceous, extends eastward from the S. E. ¼ of sec. 22, T. 61–12, and is represented by No. 959. The figure herewith (figure 35) shows three successive outcrops of granite. *A* occurs on the point in section 21, already mentioned. *B* is about three-quarters of a mile further east, and *C* is on the S. E. ¼ of sec. 22. There are three different types. It is yet to be ascertained whether their genesis is the same. Rock No. 961 shows the contact between the coarse syenyte like No. 953 as it occurs near the southwest corner of sec. 24, T. 61–12, and the granite Nos. 955 and 959.

FIG. 35. SHOWING THREE STRUCTURAL TYPES OF SYENYTE.

Sometimes in the porphyritic syenyte are bands of fine-grained syenyte, running like dikes. Sometimes bands of coarse granite, or granulyte (*i. e.*, orthoclase and quartz), run in the same manner. These last may be of chemical origin.

The relations of these different kinds of syenyte, and of granite, are expressed by figure 36, which was sketched from the bluff at the S. E. ¼ of sec. 22, T. 61–12.

Rock No. 964 shows a coarse syenyte, lying on No. 965, apparently conformably. No. 964A is from a vein (or dike) of fine granular granite, six inches wide, running across the bedding of No. 964 and blending with No. 965. No. 964B is mica schist, a condition of No. 964A in small patches. In No. 964A is a central band of orthoclase and quartz, about half an inch wide, running parallel with the sides and fading out in about four feet.

Rock No. 965 is fine-grained granite in bedded regular dip E. 30°. No. 965A is from a vein (or dike) of coarse syenyte running zigzag in No. 965.

Rock No. 966 is the lower coarse syenyte. This rises toward the left so as to appear to have been unconformable under No. 965.

It might be presumed that the massive rock (Nos. 966 and 964) wherever it occurs in this county is igneous, and No. 965 is of sedimentary origin. The above figure, however, with the veins that run from No. 965 to No. 964, and similar veins seen in the coarse syenyte in numerous other places, seem to indicate that these rocks have a common origin. The fact that No. 965 becomes gneissic with mica, and alternates with mica schist, thus apparently parallelizing the granite in the northwestern part of Vermilion lake, indicates a similarity of genesis and perhaps of age. What relation this has to the granite seen cutting the doleryte on the west side of White Iron lake is uncertain, but this seems to be a portion of the same general area. On the north shore of Birch lake the facts, so far as seen, indicate that the gabbro is later than the granite.

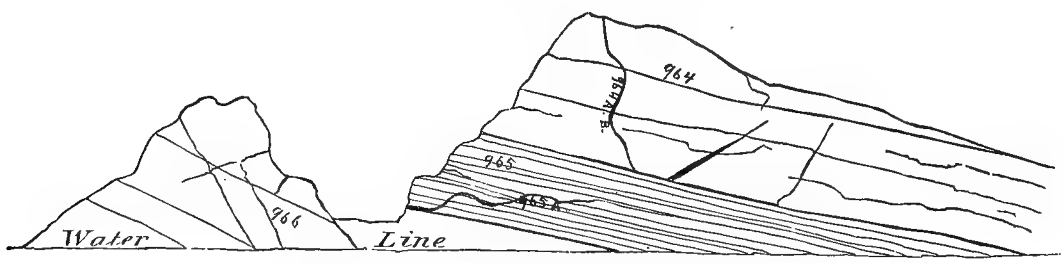

FIG. 36. SUPERPOSITION IN SYENYTE MASSES.

On the S. W. ¼ of sec. 24, T. 61–12, about a quarter of a mile east of the line dividing the syenyte from the gabbro, is a low ridge, about fifteen rods from the shore, composed of a ferruginous olivine rock which is magnetic, and really constitutes an olivinitic iron ore (No. 960). The rock appears under the moss and trees in irregular loose pieces, evidently in place. The iron in this ore gave (when the fine-grained portions were analyzed by themselves) 54.1 per cent. It contains no titanium and no chromium. When the coarser crystalline parts were examined by themselves the iron amounted to 51.30 per cent., without titanium and chromium. This rock is the same as No. 1138, which was obtained from the same place by Dr. Wadsworth. Large boulders of the same ore are on the beach near this place.

There has been some attempt to exploit this locality for iron ore, but no important economic result followed. The shafts sunk were shallow, not exceeding forty feet, and penetrated the lower member of the Animikie (?), disclosing more or less of magnetic iron ore scattered through an olivinitic quartzose rock. This member of the Animikie varies much according to its original composition and the completeness of the recrystallization to which it has been subjected by the heat of the gabbro. It is illustrated by several numbered rock samples—as Nos. 960, 402H, 404H—which represent it in its crystalline state. It extends eastward with more or less of magnetite, and has been wrought at several points in an exploratory way. The recent exploration known as the Gunflint Lake iron mine, near Akeley lake, was in the same stratum. The peculiar lithology of this stratum will be described in another place. It is the formation which, at several points, has been mentioned by geologists as

"actinolite-magnetite schist." Along with very varying amounts of actinolite the rock contains more olivine, some augite, frequently diallage, occasionally enstatite, and hornblende, and in many places the polysynthetic twinning indicates that, as claimed by Lane and Sharpless,* the mineral called actinolite is nearer grünerite, while its chemical composition is near cummingtonite.

At another point on the beach, about a quarter of a mile further west, is a small exposure of granulitic gabbro (No. 962), the rock being dark-colored, the augite being replaced, apparently to a large extent, by mica, and the olivine being rusty. Very near this place, but lying to the west of it, and indeed almost in contact with it, is a large mass of fine-grained granite, and such stone makes the boulders of the beach. This must be very near the contact line, as these large pieces form almost a continuous rock surface, broken only by opened jointage and covered somewhat by smaller blocks.

The point at the section line between secs. 23 and 24, T. 61-12, on the north side of Birch lake, is made of porphyritic syenyte, like No. 953, but a little east of the point, a few rods back in the woods, is a small ridge of fine-grained red syenyte, resembling the "red rock" back of Grand Marais. It is represented by No. 963, and it lies in a position similar to that of the fine-grained rock No. 959.

Mr. Grant examined the bay in secs. 21 and 16, T. 61-12. He found on the north side of sec. 21 the rock No. 967, in the form of a vein (or dike) cutting coarse syenyte. It is evidently a decayed or changed syenyte, some of the hornblende having been replaced by an epidote-like mineral and some changed to a greenish-silvery, foliated, chlorite-like mineral, by far the greater part being rather coarse, pinkish orthoclase. At another point, north of the section line, on the west side of the bay, he met with a coarse syenyte cut by a two-inch vein of fine syenyte. This coarse syenyte shows the hornblende is passing to mica (see sample No. 918). In other places has been noticed a mingling of black mica with hornblende in the coarse syenyte. Sometimes, also, in the gabbro the olivine is embraced in the central part of the augite crystals. No. 968 represents the rock mentioned above, where hornblende is so associated with black mica that it seems to pass into it, the rock being cut by a two-inch vein, or band, of much lighter colored, or reddish, fine syenyte. Both rocks are very quartzose.

An isolated rock, in place though, stands up in the water, in the bay, in the S. W. ¼ of sec. 28, T. 61-12, exactly like the mixed mica schist and granite described on the point in the N. E. ¼ of the S. E. ¼ of sec. 21, T. 61-12. It here dips N-N. W. 75° to 80°.

A dark dike, eighteen inches wide, runs northeast, and shows on the face of the coarse syenyte, descending to the water, in the S. E. ¼ of sec. 29, T. 61-12. Sample No. 969 is so taken that it shows the contact with a thin transverse vein, that crosses this doleritic dike of feldspathic rock, which seems to have been deposited chemically in a fissure in the dike, as it is not connected with the adjoining syenyte. Figure 37, herewith, shows this.

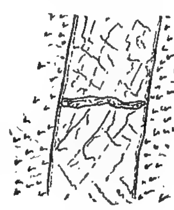

FIG. 37. FELDSPATHIC VEIN CROSSING DOLERYTE.

This dike, which consists almost wholly of hornblende where sketched above, changes gradually to mica schist (No. 970). No. 971 shows its contact with the wall of syenyte, the dike here being changed entirely to mica schist.

This change in this dike seems to indicate that other local appearances of mica schist in this syenyte, such as that seen on the point in the S. E. ¼ of sec. 21, T. 61-12, may be ascribed to the changed condition of an igneous rock, such as this undoubtedly was. In this mica schist, thus changed from some igneous rock, there is a superabundance of mica, and the white ingredient is not certainly quartz.

At a point a little further north from this dike, on the same section, is a promontory of gneiss, the rock being striped with the gneissic structure, the striping dipping south 85°, but being somewhat contorted. Some of this rock is fine-grained, hard quartzose, granite, and in it occasionally are nodules of mica schist, resembling the rock No. 970. This gneiss is represented by No. 972.

This gneiss continues westward to the town-line between Ts. 61-12 and 61-13, but is rather less distinctly banded, or bedded, than a typical gneiss, and instead coarsely fibrous in a direction coincident with the supposed prevalent dip, the coarse bars or contorted sheets, whichever they may be styled, showing a striation, or schistose structure seen from different directions, and sometimes manifesting the same illusory dip as seen in the dark gneiss or mica schist, mentioned in the northwest part of Vermilion lake. As a gneiss it is very irregular. It is more correctly an irregular alternating of two rocks than a gneissic arrangement of minerals, though the latter structure can also be seen in some large patches. The rocks so alternating are syenyte, fine syenyte, fine granite, micaceous granite, and mica schist.

On careful examination over contiguous and continuous surfaces, the mica in this rock can be seen to be replaced by hornblende, and then it becomes dark, firm and dioryte-looking, but still twisted and contorted with a light-weathering syenyte, and often mingled with a true granite of fine grain. In short, there seems to be a transition from mica schist, as before surmised, to hornblende schist, this change taking place according to the less or greater exposure and disintegrating action of the elements (compare No. 1134).

The manner in which this dark rock incloses parts of the lighter rock will allow of its being originally an igneous rock. On the other hand, the manner in which the syenyte acts, with respect to the mica schist, seems also to allow of its having been an eruptive rock.

No. 973 shows this rock in its hornblendic aspects. These (two) specimens were obtained from near contact with white-weathering, fine-grained mica granite, or gneiss, the latter being in strings, blocks and masses of all positions and shapes.

*LANE and SHARPLESS. Notes on Michigan minerals. *Am. Jour. Sci.* (3), xlii, p. 505, 1891.

No. 974 shows this rock undergoing a change toward mica schist.

Where Birch river enters Birch lake, in sec. 25, T. 61–13, the outcropping rock on the north side of the river is syenyte and gneiss, dipping northeast, while through secs. 19, 20 and 29, T. 61–12, the dip is almost invariably in a southerly direction (S. or S-S. E.), varying from 45° to 80°; further south, also, in secs. 25 and 36, T. 61-13, the dip is about south, and the rock, nearly everywhere that it is visible, is the same gneiss. But in the southwest end of the lake the rock is more hid by drift, and the shore-line consists of boulders and sand. A broad bay in sec. 36, T. 61–13, has a wide sandy beach.

This mottled schist is again represented by No. 975, got at the extreme west end of Birch lake, near the head of the bay south of the mouth of the river. The samples are dark-colored, but the face of the bluff from which they came, sometimes about half of it, is light-colored. The rock seems to have been in some places originally a fine-grained dioryte, the feldspar not being individualized, but in others to have been fissured and the fissures filled with chemically deposited quartz and orthoclase.

The round point in the northwest part of sec. 31, T. 61–12, is made up of a syenyte which in some places shows the same gneissic structure, the latter being in narrow bands dipping south and in isolated included pieces. These patches are micaceo-hornblendic. This structure seems to gradually become less and less common in this direction (*i. e.* easterly), and to be most prevalent in the northwest part of the lake.

The syenyte in the N. E. ¼ of sec. 31, T. 61–12, is massive, but embraces lenticular, elongated and irregular masses of fine-grained quartzose reddish granite, and the same also in veins. The hornblende grains have their elongation in the direction of the hitherto prevalent strike, producing a kind of structural arrangement that can be compared to that of gneiss.

There is an accumulation of fine, black, feebly magnetic sand on the beach at the S. W. ¼ of sec. 33, T. 61–12, near the mouth of a little rivulet. This probably is derived from the disintegration of some olivinitic iron ore at a short distance from the beach, similar to that seen on the north side of the lake (No. 960). This sand, on analysis, gave the following result:

Silica,	5.19
Metallic iron,	41.12
Titanium dioxide,	36.77
Alumina,	2.95
Lime,	Trace.
Magnesia,	35
Phosphorus,	None.

Drift deposits cover the rocks from this point northeastward to the S. E. ¼ sec. 28, T. 61–12, where a dark-colored, dioritic rock appears conspicuously on the shore. Here the dark ingredients of the rock are so intimately blended that they appear to be changing from one to the other (rock 978), the mica scales originating within the hornblendes in a position transverse to the fibrous grain of the hornblende. A short distance to the south of this the rock is gneiss, though on the north side, near it, but disconnected, is a similar outcrop of coarse syenyte. Some of the last weathers red and some light gray. At the next point north is a still more conspicuous exposure of coarse syenyte veined by finer red syenyte.

The Giant's range. The particular geology of the Giant's range, which consists of granite and granitic rocks, and which is accompanied closely on the southern slope by the iron deposits of the "Mesabi iron range," will be found in connection with a series of special plates devoted to the Mesabi iron range (plates 73 to 77 inclusive, in St. Louis county).

This range consists, in general, of an elevation rising from 300 to 500 feet above the adjoining average level. Toward the north the descent is generally more rapid than toward the south. The rock is mainly of granite, but more or less of greenstone, and of its modified condition the crystalline schists, accompanies the granite on both sides. The general appearance of the topography, and the general structure of the range suggest a dike-like protrusion of igneous rock into the earlier greenstones, etc., along a fault line, or a line of structural weakness; but as the igneous granitic rock extends much further north than the hypothesis of a dike-like protrusion warrants, being known as far north as the Embarras river, where crossed by the Duluth and Iron Range railroad, it is more probable that the general movement that

gave rise to the Giant's range granite was also of the nature of a regional metamorphism and fusion of the older acid rocks, over an area running about parallel with other granitic belts of the northeastern part of the state and of adjoining portions of Canada.

Iron-bearing rocks. On the southern side of the Giant's range, lying on the granite or on the greenstone, are the iron-bearing rocks of the Mesabi iron range,—the iron range having taken its name further east, where the iron-bearing strata are a portion of the Mesabi range proper, which consists essentially of gabbro. These iron-bearing strata are the lower portions of the Animikie formation, and constitute the base of the Taconic or Lower Cambrian of the state. The bottom member is usually quite coarse, and even conglomeratic at the base, but often very fine higher up. Its nature depends on that of the Archean, which was nearest, and supplied its debris. When it lies on the granite the bottom is siliceous, the quartz grains of the coarse quartzyte having a peculiar lavender-blue tint, revealing the source from which it came, for such are frequent in some parts of the granite of the Giant's range. When it lies on the greenstone, there is a liberal supply of green, hornblendic debris, which not only is mingled with the quartz grains of the quartzyte, but also constitutes sometimes independent strata of itself, the thickness of which never reaches, however, that of the quartzyte.

Sometimes in the quartzyte, but more frequently at a somewhat higher horizon, iron oxide, in the form of hematite, or, toward the east, in the form of magnetite, begins to be apparent, and this increases so as to constitute the iron ores of the Mesabi range. Mingled with this iron oxide, which is finely granular, is a peculiar form of crystalline silica, and more or less of glauconite. The various shades of chemical interchange between the glauconite, the silica and the iron oxides give various grades of purity to the ore and various colors to the rock. The siliceous rock which involves these transitions, sometimes a fine, gray or red, flint-like rock and sometimes more coarse and apparently more calcareous, and again constituting an impure iron ore, has been distinctively named taconyte,* and that term is current among the explorers and miners as indicating the presence of a more or less iron-bearing rock peculiar to the region. The most reliable, obvious character that this rock presents is an opaque, flinty ground mass in which are floating globules, nearly round, of a different color, usually red, making a spotted bloodstone. But the iron oxides and the silica are not always so distinctively grouped, and the result is an indefinite blending of silica and iron oxide in which the colors are in streaks or bands. The rock also passes into strata which are in large part made up of fragmental debris. It is in connection with this rock that the great iron bodies of

*H. V. Winchell. *Twentieth Annual Report*, p. 124.
J. E. Spurr. *Bulletin No. X*, pp. 248–49.

the Mesabi range have been formed, and they are sometimes more than 200 feet in thickness. The iron is granular and pure, and can be mined by the cheapest methods on a grand scale. The prevalent method is by steam shovel which, with one movement, transports the product from its place in the mine directly to the railroad car. The entire thickness of the taconyte member is from 500 to 1,000 feet, but no ore body of this thickness has yet been discovered.

Above the ore horizon are the black slates of the Animikie, which, with their alternations of gray quartzyte, reach a greater thickness, amounting, perhaps, to several thousand feet. At the bottom of the slates is seen sometimes an interrupted layer of gray limestone. Where the strike of the gabbro protrusion crosses the Animikie, and especially the lower portion of it, the Animikie has been greatly modified and crystallized, giving rise to magnetic ore and to interesting petrographical phenomena, which are more fully mentioned elsewhere. These features are developed between Birch lake and the Duluth and Iron Range railroad. The effect of the gabbro, which was introduced after the completion of the Animikie, was to consolidate the fragmental quartzyte into a crystalline one in which those ingredients which were not originally quartz have served for the generation of several minerals that are usually found only in the basic igneous rocks, such as diallage, enstatite, olivine and hypersthene. Besides these are found also, with magnetite, hornblende (actinolite?), augite and grünerite, as well as striated feldspars. Thus, in the presence of a practically limitless supply of silica, were generated, under the action of the heat of the gabbro, a number of the most basic of rock-making minerals. In general this belt of altered quarzyte has been designated by some "actinolite magnetite schists,"* although actinolite is a minor constituent. In the reports of the survey this belt has been referred to as olivinitic quartzyte, and olivinitic magnetite. It is not markedly separated stratigraphically from the true iron-bearing member, in some places, but the two are closely related.†

The strong topographic characters of the Giant's range subside in the eastern limits of this plate, and in the vicinity of Birch lake, where the gabbro strike intersects it, there is a general falling away of the level of the granitic area, and the gabbro range becomes the chief topographic feature. At the same time, toward the east, the granitic area itself dwindles to a narrower belt, and it is finally entirely lost, being overwhelmed by the later basic intrusive. This takes place in Lake county.

The Mesabi range is the elevation caused by the gabbro. Owing to the prevalence of the drift, southward from the Giant's range, but few rock exposures are

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* A. H. ELFTMAN. *Twenty-second Annual Report*, p. 159.
W. S. BAYLEY. *American Journal Science* (3) xlvi, 176.

† Since the above was written it has been ascertained that the greater part of the olivinitic iron ore of the Mesabi range as above described, and the other peculiarities of mineral combination produced by the gabbro, are no part of the Mesabi range of the Animikie formation, but are modified conditions of the Keewatin at points where the Keewatin locally carried jaspilyte, due to the gabbro. Consult the chapter on Structural Geology. The Animikie proper is not known in this county further east than the vicinity of Iron lake in T. 60-13.

known, and the actual boundary of the gabbro, southward from the Duluth and Iron range railroad, whether on the west or on the east, is unknown. The plate represents this belt but approximately. To the eastward of this railroad the width of the gabbro belt is greater, but cannot be expressed with definiteness. Its relation to the lavas represented at the southeast corner of this plate is not ascertainable by anything known within this area, but is stated in connection with the description of the southern part of St. Louis county, and in the discussion of the structural geology (vol. v).

The gabbro is favorably exposed at Allen and Allen junction, and at various places south and east of those points, rising in irregular, low rocky domes, about ten to thirty feet above the surrounding country, thinly covered by a coarse drift which is frequently in the form of ridges and hills of boulders and coarse gravel, suggesting a morainic belt. At points further south Mr. A. D. Meeds, who examined the region, has reported but few outcrops of gabbro. They are mentioned in the special descriptions (foregoing) of the various towns in which they occur. The most remarkable is that known as Grandmother hill, in T. 57–13, on the line between sections 8 and 17, which is of low conical form, with an abrupt elevation of about 250 feet, according to Mr. Elftman, above the surrounding general surface, which is rather wet and swampy. The rock of this hill (No. 187E) is a rather fine-grained, gray gabbro. Other exposures are along the branches of the Cloquet river, viz., sections 19 and 30, in T. 55–12, and at points already mentioned further south, in the description of plate 66.

The surface lavas, represented in the southeast corner of this plate, are the same that appear at the lake shore at Duluth and eastward, and are more fully shown on the preceding plate (66). They have been visited by Mr. Meeds, who collected from the town next south the rock samples Nos. 30M to 35M. The samples are not amygdaloidal, but porphyritic, fine diabases, and resemble those which at Duluth follow immediately after the massive gabbro, some of them being of the red-rock series. They have not been microscopically examined, but their affinities are apparent. It is evident that the succession from the gabbro to these surface rocks here is of the same general character as exhibited at Duluth, the gabbro being the reservoir or deep seated source from which the lavas issued, differing only because of environment at the time of cooling. The acid element is erratic and occasional, depending upon the amount of admixture of the basic intrusion, at any certain point, with the rock resulting from the fusion of the clastics. They alternate and intersect, but were practically of about the same date.

Rock samples collected in the north part of St. Louis county are as follows: Nos. 358–442; 864–947; 952–978; 1001–1003; 1015–1023; 1132–1140; 1447–1452; 1501–1514; 1546–1572; 1617–1642; 1688–1708; 1710–1714; 1786–1795; 1954–1965; 1981–2029; 2092–2128; 2135–2144; 2275–2280.

Series of U. S. Grant: Nos. 115G–127G; 129G–131G; 278G–298G; 1009G–1016G; 1021G–1024G; 1056; 1057; 1070G–1099G.

Series of A. H. Elftman: Nos. 1E–26E; 139E–145E; 187E; 259E.

Series of A. Winchell: Nos. 1W–92W; 107W–125W; 136W–137W; 151bW–173W; 282W–293W; 988W–999W.

Series of H. V. Winchell: Nos. 1H–29H; 160H–212bH; 286H–406H; 418H–419H.

CHAPTER XI.

THE GEOLOGY OF LAKE COUNTY.

(PLATE 68.)

BY N. H. WINCHELL.

Situation and area. This county, situated between St. Louis and Cook counties, spans the geology of the Taconic and the Archean, extending as a broad parallel-sided belt from lake Superior to the international boundary. Within its area are illustrated most of the prominent geological features, and many of the interesting economic as well as scientific problems that have arisen during the prosecution of the survey.

Three chapters, covering the belt of country containing the most of the iron ores, will be found to give more details of the field observations, and also more detailed mapping, than the present chapter. These are chapters lxxviii, lxxix and lxxx.*

Since the publication of the Twenty-third Report numerous observations have have been recorded, but remain unpublished, in the note-books of Grant, Elftman and N. H. Winchell. These later examinations, serving to correct some former ideas and supplementing others, and also extending our knowledge into the interior of the county in greater detail, are the chief basis of this chapter. The rock samples of these later observations are listed in the Twenty-fourth Annual Report.

Topography. Lake Superior being 602 feet above sea level, the county is found to rise about 1,250 feet higher, the greatest elevations being on the Mesabi range

* The examination of this large area has been carried on since 1878, but with interruptions. Preliminary field descriptions and geological conclusions have been published in the annual reports as follows. The list is here given in order that the original data may be consulted, if it ever becomes necessary, but the summary given in the present chapter is intended to supersede all former statements when they are found to differ:

Ninth Report, pp. 25–42; 85–92. This deals with the rocks of the lake Superior shore, and those collected along the northern borders of the county, and on Bassimenan and Fall lakes; by N. H. WINCHELL.

Tenth Report, pp. 37–42; 61–64; 90–98; 109–116. This deals with the rocks of the lake Superior shore and those from the vicinity of Ogishke Muncie lake; by N. H. WINCHELL.

Fifteenth Report, pp. 319, 320; 327–333; 341–382; 390; 392–399. This deals with the northern part of the county; by N. H. WINCHELL.

Pages 58–117; 119–171. This deals with the northern part of the county; by A. WINCHELL.

Pages 406–413; 416–419. This deals with Bassimenan, Knife, Pseudomesser and Ogishke Muncie lakes; by H. V. WINCHELL.

Sixteenth Report, pp. 89–112. Northern part of the county; by N. H. WINCHELL.

Pages 195–328; 379, 380; 386, 387. Northern part of the county; by A. WINCHELL.

Seventeenth Report, pp. 96, 97; 99–103; 110–128; 138–144. The northern part of the county, especially with T. 63–9, and also with a trip across the country to lake Superior; by H. V. WINCHELL.

Pages 151; 161–168; 186–191; 194–200; 202; 204–210; 213–215. Northern part of the county, and also with a trip across the country to lake Superior; by U. S. GRANT.

Twentieth Report, pp. 39–82; 90–95. This deals especially with the outlines of the granite areas of the Kawishiwi river, Snowbank lake and Kekequabic lake; by U. S. GRANT.

Pages 181–289, for the abandoned beaches, etc., of the whole north coast of lake Superior. The beaches in Lake county are described on pp. 237–242; by A. C. LAWSON.

Twenty-first Report, pp. 155–159; 143–152. Deals with the northern part of the county, and especially with Snowbank lake and with the nature of the rock called muscovadyte; by N. H. WINCHELL.

Pages 5–66. Deals with the northern part of the county, especially with the district just south of the Ottertrack lake; by U. S. GRANT.

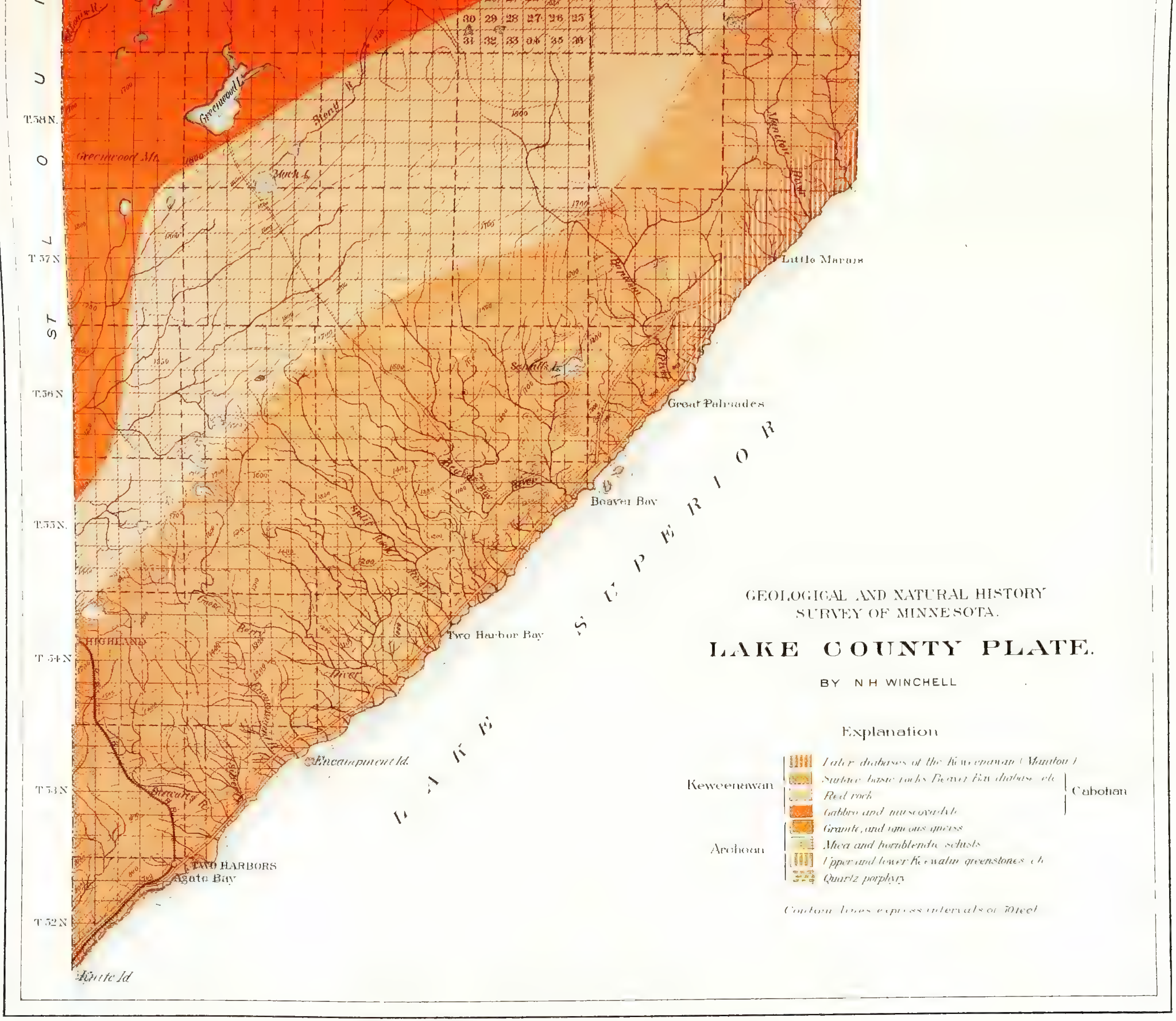
Twenty-second Report, pp. 141–180; 182–189. Lake county in general, especially with the anorthosytes, and the Snowbank lake area; by A. H. ELFTMAN.

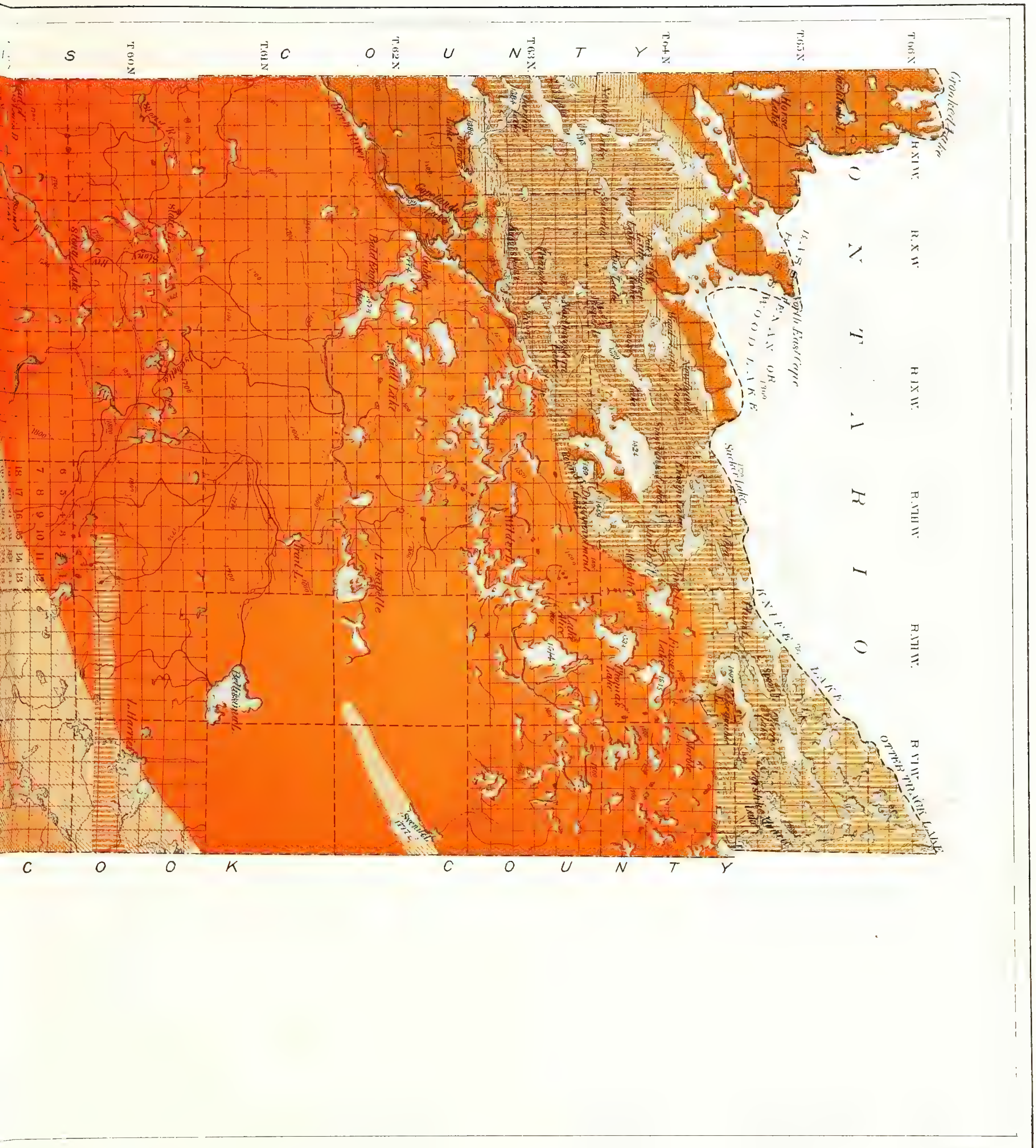
Twenty-third Report, pp. 224–230. Deals with the gabbro; by A. H. ELFTMAN.

Bulletin viii, pp. 1–23; the anorthosytes; by A. C. LAWSON.

Pages iii-xxx. The Norian in general; by N. H. WINCHELL.

Twenty-fourth Report. Deals with the greenstones and the gabbro, and especially with the regions of the Kawishiwi river and Snowbank lake; by N. H. WINCHELL and U. S. GRANT.


GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.
LAKE COUNTY PLATE.
BY N.H. WINCHELL
Explanation
Keweenawan
Later diabases of the Keweenawan (Manitou)
Surface basic rocks Beaver Bay diabase etc
Red rock
Gabbro and muscovadyte
Cabotian
Archean
Granite and igneous gneiss
Mica and hornblende schists
Upper and lower Keewatin greenstones etc
Quartz porphyry
Contour lines express intervals of 50 feet
LAKE SUPERIOR
ST LOUIS
T.58 N.
T.57 N.
T.56 N.
T.55 N.
T.54 N.
T.53 N.
T.52 N.
Greenwood L.
Greenwood Mt.
Little Marais
Great Palisades
Beaver Bay
Two Harbor Bay
Encampment Id.
TWO HARBORS
Agate Bay
HIGHLAND
Knife Id.


S C O U N T Y
T.60N
T.61N
T.62N
T.63N
T.64N
T.65N
T.66N
R.XIW.
R.XW.
R.IXW.
R.VIIIW.
R.VIIW.
R.VIW.
O N T A R I O
C O O K C O U N T Y
Crooked Lake
North East Cape
KNIFE LAKE
OTTER TRACK LAKE
Saganaga Lake
Birch River
L. Isabelle
Bald Eagle
Gull Lake
Trout L.
Bellissima L.
Sawbill L.

(Photo by O. J. Midthun.)

FIG. 1. POINT ON SEC. 11, T. 53-10, NEAR ENCAMPMENT ISLAND.

FIG. 2. VIEW IN CATHEDRAL BAY.

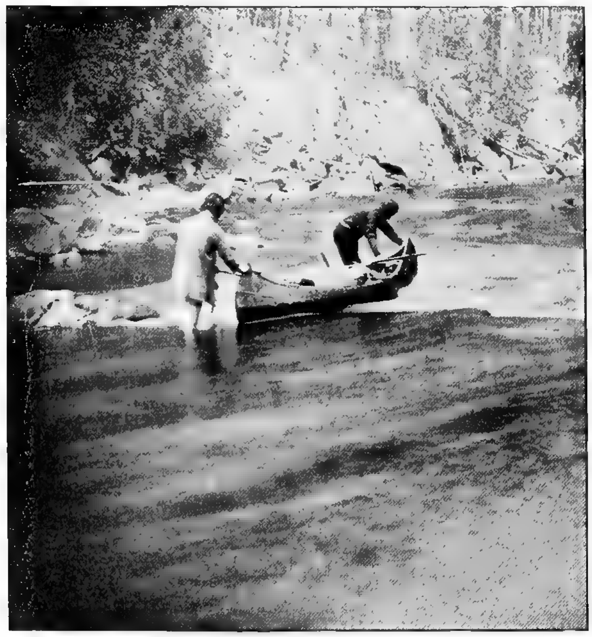


FIG. 3. DESCENDING RAPIDS IN THE KAWISHIWI RIVER. (p. 267.)

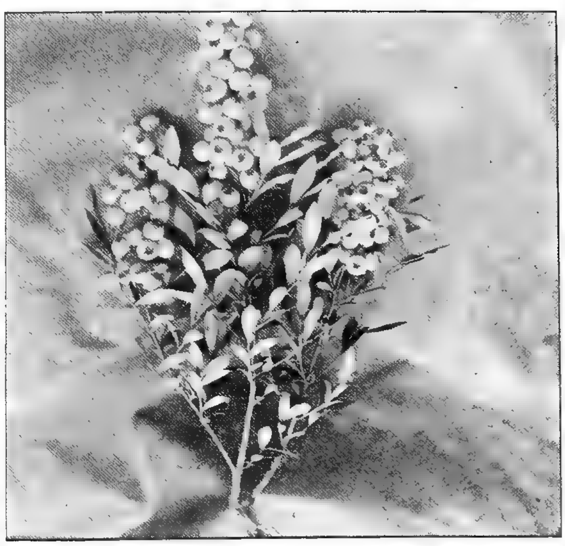


FIG. 4. FRUITING BRANCH OF THE COMMON BLUEBERRY.

across the south central part of the county, viz.: in Ts. 58–8, 58–9, and 58–10, and in Ts. 59–6 and 59–7, where the broad swells of the red rock rise to 1,800 or 1,850 feet above the sea. This is a broad, undulating plateau, generally deeply covered by drift, from which nearly all the streams of the county take their source. Southward from this plateau there are comparatively few lakes, but toward the north they are very numerous, and in the northern one-third part of the county they are so frequent, and the streams are so large and steady, that most of the travel is done by canoe (plate E E, figure 3). Here are found Snowbank, Moose, Wilder, Alice, Fraser, Thomas, Kekequabic, and many other lakes, while along the international boundary is a continuous and deep water-course, mostly formed by lakes, such as Ottertrack, Knife, Bassimenan (Basswood) and Crooked lakes. These more northern lakes lie in rock-bound basins, and their outlets are over the rocky rims, which generally are not visibly cut back by erosion. The rocky structure, in its main trend, is expressed by the forms and direction of elongation of these lakes. The water along the northern boundary descends westward, and reaches the valley of the Red river of the North, and finally enters Hudson's bay. Ottertrack lake, at the northeastern corner of the county, has an elevation of 1,387 feet; Knife lake 1,382 feet; Sucker lake 1,330 feet; Bassimenan lake 1,300 feet, and Crooked lake, at the northwest corner of the county, 1,245 feet.

Altitudes in feet above the sea.

Determined by aneroid barometers, excepting several lakes designated by asterisks (*), whose hights are known by leveling:

	Feet.
Fox lake,	*1,539
Ogishke Muncie,	*1,488
Dike lake,	*1,491
Zeta lake,	*1,490
Epsilon lake,	*1,460
Delta lake,	*1,469
Gamma lake,	*1,470
Beta lake,	*1,475
Alpha lake,	*1,495
Kekequabic lake,	*1,497
Knife lake,	*1,381
First lake west of Knife lake,	*1,371
Second lake west of Knife lake,	*1,367
Third lake west of Knife lake,	*1,361
Carp lake,	*1,355
Sucker lake,	*1,330
Bassimenan lake,	*1,300
Newton lake,	*1,307
Long lake,	*1,337
Friday lake,	1,388
Fall lake,	*1,313
Garden or Eve lake,	*1,384
Farm lake,	1,386
White Iron lake,	1,395
Birch lake,	1,410
Copeland's lake,	1,439
Fork of the Kawishiwi river, sec. 26, T. 63–10,	1,435
Crab lake and northeast elbow of Kawishiwi river in sec. 15, T. 63–9,	1,487
Ridges about ½ mile north of the Kawishiwi river, in the northwest part of T. 63–9, about	1,730
Large lake on the Kawishiwi river, in the southeast part of T. 63–9,	1,491

	Feet.
Lake of Kawishiwi river, sec. 33, T. 63-8,	1,520
Wilder lake,	1,540
Lake Alice,	1,544
Triangle lake,	1,490
Northwestern lake,	1,475
Bassimenan (Basswood) lake,	*1,300
Sucker lake,	1,330
New Found lake,	1,331
Wind lake,	1,359
Moose lake,	1,339
Jasper lake,	*1,387
Snowbank lake,	*1,424
Ensign lake,	*1,342
Disappointment lake,	1,499
Disappointment hill, sec. 35, T. 64-8, about 1 mile east of this lake,	1,850
Gabbro lake,	1,474
Bald Eagle lake,	1,478
Lake on the Isabelle river, secs. 29 and 32, T. 62-8,	1,533
Lake Isabelle,	1,570
Bellissima lake,	1,650
Harris lake	1,580
Slate lake,	1,640
Stony lake,	1,668
Sand lake,	1,674
Greenwood lake,	1,705
Greenwood mountain, sec. 30, T. 58-10, about 1½ miles south of this lake,	1,850
Lakes in the west part of T. 59-11, at the head of the St. Louis river,	1,685
Seven Beaver lake,	1,675
Pine lake,	1,705
Pike lake,	1,700
Lake in sec. 22, T. 59-9,	1,745
Muck lake, at the head of Stony river,	1,755
Smokehouse lake,	1,740
Clear lake,	1,704
Adams lake,	1,800
Schaff's lake,	1,089
Bear lake,	1,160
Lake Superior, mean, 1870-1888, above mean tide sea level,	*602

Portages on the Stony river.

From Birch lake (1,410 feet above the sea) to Slate and Pike lakes and the lake in sec. 22, T. 50-9.

No.	Length.	Location.	Ascent in feet.	To altitude above the sea.
1.	⅛ mile	S. E. ¼ sec. 30, T. 61-11,	10	1,420
2.	¼ mile	N. E. ¼ of N. E. ¼ sec. 31, T. 61-11,	20	1,440
3.	1 rod	S. W. ¼ of N. E. ¼ sec. 31, T. 61-11,	1	1,441
4.	¼ mile	North part of S. E. ¼ sec. 31, T. 61-11,	6	1,447
5.	⅛ mile	Crossing south line of section 31,	24	1,471
6.	⅓ mile	N. E. ¼ of S. E. ¼ sec. 6, T. 60-11,	15	1,486
7.	30 rods	N. W. ¼ of N. W. ¼ sec. 8, T. 60-11,	20	1,506
8.	½ mile	W. ½ of S. W. ¼ sec. 8, T. 60-11,	69	1,575
9.	¼ mile	S. W. ¼ of N. E. ¼ sec. 17, T. 60-11,	15	1,590
10.	¼ mile	North edge of S. W. ¼ sec. 16, T. 60-11,	5	1,595
11.	⅛ mile	S. W. ¼ of N. E. ¼ sec. 16, T. 60-11,	7	1,602
12.	8 rods	S. W. ¼ of S. W. ¼ sec. 10, T. 60-11,	5	1,607
13.	¼ mile	Central part of sec. 10, T. 60-11,	5	1,612
14.	Short rapids.—N. W. ¼ of S. E. ¼ sec. 10, T. 60-11,		2	1,614
	The usual portage instead of the last three is three-fourths mile long, from the northwest corner of section 15 to the N. W. ¼ of the S. E. ¼ of sec. 10.			
15.	¾ mile	East part of section 11 and west part of section 12,	10	1,624
16.	½ mile	S. ½ of section 12, T. 60-11,	10	1,634
17.	1½ mile	Current and rapids to Slate lake,	6	1,640
18.	¾ mile	Across eastern part of sec. 17, T. 60-10, to Chub lake,	15	1,655
19.	⅔ mile	Southeast through N. W. ¼ sec. 21, to Stony river at Headquarters camp, near the centre of this section,	10	1,665

No.	Length.	Location.	Ascent in feet.	To altitude above the sea.
20.	Short rapids.—N. W. ¼ sec. 34, T. 60–10, to Stony lake,		3	1,668
21.	1 mile	Crossing N. W. ¼ sec. 35 to Pike lake,	32	1,700
22.	1 mile	S. ½ of sec. 31, T. 60–9,	28	1,728
23.	Current and rapids to lake in sec. 8, T. 59–9		11	1,739
24.	Current and rapids to lake in sec. 22, T. 50–9,		6	1,745

Portages on the south branch of Isabelle river.

In ascending the Isabelle river from Bald Eagle lake (1,468 feet above the sea) a portage about a half a mile long is made in sec. 5, T. 61–9, with ascent of 50 feet, to 1,518; and two short portages successively ascend two and five feet in the south part of sec. 34, T. 62-9, to the north of this south branch, near the middle of the east half of this section 34, at 1,525 feet.

No.	Length.	Location.	Ascent in feet.	To altitude above the sea.
1.	10 rods	S. W. ¼ of sec. 3, T. 61–9,	1	1,526
2.	⅛ mile	S. E. ¼ of N. W. ¼ sec. 9, T. 61–9,	3	1,529
3.	20 rods	N. ½ of sec. 16, T. 61–9, -	4	1,533
4.	½ mile	S. ½ of sec. 16, T. 61–9,	20	1,553
5.	2 rods	N. W. ¼ of N. E. ¼ sec. 29, T. 61–9,	5	1,558
6.	⅕ mile	N. E. ¼ of N. W. ¼ sec. 29, T. 61–9,	4	1,562
7.	25 rods	North part of S. W. ¼ sec. 29, T. 61–9,	8	1,570
8.	⅛ mile	Near the centre of the S. W. ¼ sec. 29,	6	1,576
9.	5 rods	S. W. corner of sec. 29, T. 61–9, -	7	1,583
10.	¾ mile	W. ½ of sec. 32, T. 61–9,	45	1,628
11.	⅓ mile	S. W. ¼ of S. W. ¼ sec. 5, T. 60–9,	15	1,643
12.	2 rods	N. W. corner of sec. 8, T. 60–9,	3	1,646
13.	⅕ mile	East part of N. W. ¼ sec. 8, to a small lake,	14	1,660
14.	⅛ mile	S. E. corner of sec. 8, T. 60–9,	5	1,665
15.	¼ mile	S. W. ¼ sec. 9, T. 60–9,	15	1,680
16.	½ mile	S. E. ¼ sec. 9, and S. W. ¼ sec. 10, T. 60–9,	20	1,700
17.	10 rods	West edge of S. E. ¼ sec. 10, to lake in the N. E. ¼ of sec. 15, T. 60–9,	4	1,704
18.	⅔ mile	From foregoing lake through N. ½ of sec. 14, T. 60-9, to Clear lake,	9	1,704
19.	1 mile	From Clear lake southwest to the South branch of Isabelle river in the south edge of the N. E. ¼ of sec. 22, T. 60–9,	20	1,724
20.	15 rods	North edge of S. E. ¼ sec. 22, T. 60–9,	7	1,731
21.	10 rods	Central part of S. E. ¼ sec. 22, T. 60-9, to lake on the south line of this section,	7	1,738
22.	½ mile	From foregoing lake southwest through the N. W. ¼ of sec. 27, T. 60-9, to Smokehouse lake,	2	1,740

By a series of comparative aneroid readings, the following approximate hights above lake Superior were ascertained in ascending the Baptism river. The simultaneous readings, extending from 8:00 o'clock to 12:30 p. m., were made by Mr. B. Juni.

	Feet.
Hight of line of bearing of rock No. 127, where it crosses Baptism river,	27.5
Conglomerate outcrop,	40.0
Foot of first fall,	82.5
[Thirty-five feet fall.]	
Top of first fall,	117.5
Foot of second fall,	140.0
[Thirty-five feet fall.]	
Top of second fall,	175.0
Foot of third fall,	190.0
[Sixty feet fall.]	
Top of third fall,	250.0
Foot of fourth fall,	282.5
[Thirty-five feet fall.]	
Top of fourth fall,	317.5
N. W. ¼ N. E. ¼ sec. 4, T. 56–7,	335.0

Throughout most of the county, as represented on the accompanying plate, contour lines have been drawn, at intervals of fifty feet, but these are often only approximate, and many minor irregularities have been disregarded. They are sufficient to express simply the grand outlines of the surface. The method followed

in determining these topographic outlines is described in the introduction to this volume, but special care was taken to determine the hights of lakes and rivers, along the more common routes of travel. Some data were furnished by preliminary railroad levels, and some leveling was done by the survey.

Some townships, not yet subdivided by the United States government, have not been examined except in a very general way. In one of these is Bellissima, one of the largest lakes in the county.

THE GEOLOGICAL FORMATIONS.

The Keewatin.

In considering the geology proper of this county the oldest rocks will be described first and the most recent last. Under the term Keewatin are included all the clastics of the Archean. These are always more or less metamorphosed, but in nearly all cases their fragmental origin is still plain. The very bottom of the Keewatin, however, consisting of greenstones, is frequently massive, and apparently of originally igneous origin.

Structurally the Keewatin is divisible into two parts, viz., Lower Keewatin and Upper Keewatin, and petrographically into four parts, owing to metamorphism. These four parts will be treated separately, and are as follows: (1) Greenstones and iron ores; (2) Evident clastics, etc., and iron ores; (3) Mica schists; (4) Muscovadyte and iron ores. The igneous rocks are divisible into: (1) Granite and igneous gneiss; (2) Porphyry; and (3) Later dikes of diabase. The igneous rocks, with the exception of some of the bottom greenstones, are plainly of later date than the clastics with which they are associated, and are of different ages. To this statement the quartz-porphyries may be an exception.

The Lower Keewatin runs in two main belts across the county. Beginning at Garden lake, on the western boundary, T. 63-11 west, where the two belts seem to be united in one, the southern arm can be traced along the north side of the Kawishiwi river, having a width of three or four miles, including the region of Triangle, Northwestern and Jasper lakes. With a rapid contraction it runs to the south of Snowbank lake, but sends a northeastward spur between Moose and Snowbank lakes to the vicinity of Flash lake. Eastward from Snowbank lake this belt is encroached on by gabbro, and suffers a change to muscovadyte and allied rocks, and it can hardly be distinguished as Kawishiwin greenstone until it emerges in the high range which appears along the south side of Kekequabic and Ogishke Muncie lakes.

The northern belt maintains its superficial connection with the southern until in the vicinity of Saturday lake. Its width northward from Saturday lake is indefinite, as it is cut by granite and is altered gradually to mica schists. It is seen at the southern end of Bassimenan (Basswood) lake and about the shores of Urn lake. It

also appears between Moose and Wood (or Wind) lakes, and is supposed to extend northward to the granite of Basswood lake. It occurs again north of Knife lake, on Hunter's island, constituting extensive hilly ranges.

This greenstone is not unlike that which appears in a similar way in St. Louis county, and especially about Ely. It consists of two parts which are not easily separated, either in the field or in petrographic characters, but which, theoretically, have different origins, and which sometimes are quite distinct in outward characters. One part is massive, or at least shows no evidence of clastic characters, and is supposed to be the older; the other usually shows fragmental characters, and is sometimes quite plainly bedded by sedimentary assortment. The latter contains the greater portion of the iron ores of the county, at least those that are not an integral part of the gabbro. Together these two members constitute the Kawishiwin, the oldest known rock formation of the state.

The Upper Keewatin lies non-conformably on the Lower Keewatin, and occupies the space intervening between the foregoing described belts of the Lower Keewatin. It is first observable on the south shore of Saturday lake (Nos. 2145, 2145A), where it contains greenstone pebbles from three to ten inches in diameter, and exhibits an unconformable relation to the Lower Keewatin. It is also seen as a conglomerate on the north side of the same lake. It is not known on Urn lake, but, striking eastwardly and then southeastwardly, appears at the southwestern corner of Pine lake and extensively in the northern part of T. 63-9. It here resumes its northeastern direction and runs in a wide belt between Moose and Snowbank lakes, lying on both sides of the Lower Keewatin spur mentioned. Further northeast it is found about the western and northern shores of Snowbank lake, where it is converted to mica schist and is intruded by granite. Through here the conspicuous part of the Upper Keewatin is a conglomerate, but it is also finer, making argillytes, graywackes and green schists. It also forms the northern shores of Disappointment lake. About Ensign lake the shores are of finer-grained, often sericitic schist, and the same is true further northeast to Knife lake. These schists, which embrace jaspilyte ore, are of Lower Keewatin age. But about Kekequabic and Ogishke Muncie lakes the Upper Keewatin is quite coarse and often conglomeratic, and, as such, it continues to Saganaga lake, where it lies non-conformably upon the Saganaga granite. South from Ogishke Muncie lake it lies non-conformably upon the greenstones of the Lower Keewatin, as illustrated in the chapter (xxiii) on the Fraser lake plate. Its remarkable development here has given the basal part of the Upper Keewatin the name Ogishke conglomerate.

Although these two non-conformable parts of the Keewatin are well known, and are often observable within the area of this plate, no attempt has been made to

show their separate areas on the accompanying plate. Indeed the most of the field-work was done before the significance of this conglomerate and its stratigraphic place in the Archean were correctly understood, and it was then too late to trace it out in the field in detail.

Metamorphism of the Keewatin. There are two ways in which the Keewatin varies in character. One is due to the original differences in the debris that went into its composition, and hence it becomes noticeable in crosssing the strike of the bedding as it outcrops, from southeast to northwest. The other variation is due to metamorphism. This metamorphism may come on to any part of the Keewatin, and its product varies not only in consequence of the original sedimentary differences, but in consequence of greater or less nearness to the centre of metamorphic activity. As such centres of activity are usually marked by actual intrusions of igneous rock, which finally are developed into bosses and irregular areas of igneous granite or gabbro, it is nearly always the case that metamorphism is intensified in the direction toward the areas of known igneous rock. It happens, however, that a belt of metamorphism by granite crosses this county, but oscillates noticeably in intensity because it is not accompanied throughout by the appearance of igneous rock.

Again, the metamorphism of the Keewatin depends on the kind of igneous rock which is concerned in the production of the alteration. For instance, the alteration produced by the granitic intrusions, or by the force which accompanied them, uniformly gave rise to mica schists, when the original rock was clastic and of an acid nature, but to hornblendic schists when the basal greenstones were affected. Dark gneisses, micaceous and hornblendic at the same time, and usually more or less siliceous, were produced when the granitic action operated on a basic clastic rock, such as most of the iron-bearing rocks of the Kawishiwin. The gabbro, however, when in contact on the Keewatin invariably produced a rock which in general may be styled muscovadyte; and this is true whether the Keewatin sediments had been already altered to mica schist by an earlier granitic intrusion, or whether the gabbro comes on to the Keewatin without such prior metamorphism. The nature of this muscovadyte varies with the nature of the original, but the typical muscovadyte is that which is derived from a basic clastic containing at the same time some free quartz. This is the rock which has sometimes been called noryte, and has also been considered a peripheral condition of the gabbro itself. It varies also to the rock which has sometimes been designated in Minnesota actinolite-magnetite-schist. This takes place where the original rock contained iron ore or jaspilyte. It also varies to the olivinitic iron ore, so-called. Indeed this metamorphism, which is illustrated by many specimens described in the chapter on

microscopic petrography, generates various ferro-magnesian minerals, the most abundant being hypersthene, olivine, cummingtonite ("grünerite"), enstatite, biotite, augite, diallage. With these appear, according to the composition of the original greenstone, plagioclase, quartz and magnetite, in varying amounts. It is apparent therefore, that, as a general principle, the metamorphic rock produced by proximity to an igneous intrusive, causes the generation of those ferro-magnesian minerals, which are characteristic of the intrusive rock, thus tending to bring the metamorphic and the igneous rocks concerned into a greater degree of petrographic similarity.

Geographically these different metamorphic rocks are characteristically distributed in Lake county. The granite about Bassimenan lake is intruded upon the Lower Keewatin, converting it into mica schist and hornblendic rock throughout a belt which enters the county from St. Louis county, about two miles in width, but which turns about the southern periphery of that granite boss, crossing the general strike of the Lower Keewatin, and gradually becomes narrower and almost fades out before it leaves the state near Sucker lake.

In the same manner a narrower belt of mica schist surrounds the granitic boss of Snowbank lake, but in this case the granitic intrusion is upon the Upper Keewatin, in part, and in part upon the southern arm of the greenstones. These are therefore both converted to mica schist. This mica schist is visible about the western shores of Snowbank lake, round the southern confines of the same lake, and the southwestern portions of Disappointment lake. The limits of these areas of mica schist cannot be given exactly. Mica schist has not definite characters, and it fades out imperceptibly into less and less micaceous rock. In the case of the region of Snowbank lake, however, the mica schist belt is rather narrow, in keeping with the smallness of the granitic intrusion. Nearly everywhere about Snowbank lake, as well as Disappointment lake, the original rock was coarsely fragmental, even conglomeratic, and these fragmental variations are plainly visible still in the mica schist.

It was at a later date that the gabbro invaded the same rocks along the southern spur of the Kawishiwin, and its effect is seen in the production of a peculiar, often crumbling, grayish rock called muscovadyte. The mica schist at the southwestern angle of Disappointment lake, apparently a part of the Lower Keewatin, becomes changed, in passing eastward along the shore, to a conglomeratic muscovadyte which embraces the iron ores seen at Cheadle's on the south shore of that lake. Further northeast this muscovadyte runs to Ima lake, and to the southwestern confines of Kekequabic lake, where it turns more eastwardly, following the northern border of the gabbro. Along the northern shores of Kawishiwi river, in T. 63-9, this rock is coarse, with much biotite. The details of the petrographic characters of these metamorphic rocks are given in the chapters dealing with petrography. The local-

ities can be studied by examining the descriptions connected with the rock samples numbered at the end of this chapter.

(1). The greenstones and iron ores. The lowest (and oldest) iron ore horizon known in Minnesota is that which is found in the clastic greenstones of the Kawishiwin. It is fairly represented in Lake county, in Ts. 63–8, 9 and 10, where it has been superficially explored and tested at several points. It also appears about the southern limits of Moose lake, in T. 64–9, where a considerable diamond-drilling has been done. So far as known, these deposits have not been shown to be of important economical value in Lake county.

In T. 63–9, on the west line of section 16, at about 340 paces north of the quarter-post, is the southern slope of a prominent ridge of greenstone, or diabase, running in a northeast and southwest course, its summit being near the northwest corner of section 16. This rock shows in places, and especially on the northern slope of the hill, an agglomeratic structure like that seen in the greenstone at Ely, the separate masses being entirely of greenstone and indistinctly outlined on the surface. This agglomeratic structure, which is apparently a feature of the upper part of the more evidently massive portions of the Kawishiwin, or near the bottom of the fragmental part, gives place further north to a conglomerate of greenstone pebbles, which strikes northwest and southeast. From this place these greenstones extend widely over sections 9 and 4, but in sections 8 and 5, and in the northwestern part of section 5, the overlying conglomerate hides it.

This greenstone contains large ridges of jaspilyte in N. E. ¼ sec. 8, T. 63–9, and in the S. W. ¼ sec. 4, some of them being continuous for half a mile. The individual bands are red and black, and much crumpled, the ore being very largely of magnetite. Debris from these ridges is abundantly mingled, as at Tower, with the overlying conglomerate. There is good reason for believing that there exist in the northern part of this town ore deposits of value, and that they will yet be brought to light by further exploration.

Other localities of jaspilyte are in N. W. ¼ N. W. ¼ sec. 10 and S. W. ¼ N. W. ¼ sec. 4, on the ridge which lies between two small lakes.

The greenstone which surrounds these lenticular bodies of ore is massive and diabase-like, as if it were of direct igneous origin, and in that respect is somewhat different from that seen at Tower. This condition, however, is believed to be of secondary date and origin. It is a feature which is not confined to the Kawishiwin fragmentals, but affects also the overlying conglomerate. There is a belt or axis of metamorphic activity which extends from Kekequabic lake to Snowbank lake, giving rise to granitic bosses at these points, but further southwest only appearing in the hardening and more or less recrystallizing of the older rocks. This force appears to have given a secondary phase of apparent igneous origin, not only to the older clastic greenstones, but to the conglomerate of the Upper Keewatin, as will be noted later.

There is a great range of this greenstone, forming hills which rise 200 feet above Moose lake, running through the country south of Moose lake. It was examined S. W. ¼ S. W. ¼ sec. 32, T. 64–9. There is a conglomerate here which is apparently interstratified between two greenstones. One of these is agglomeratic, but has forms of greenstone as pebbles two or three inches in diameter, of differing grain and texture, though these are scarce. These are evidence of fragmental accumulation, separating two larger masses of what appears to be igneous rock. A little west of the centre of sec. 32, T. 64–9, is a display of dark jaspilyte, extending east and west in the greenstone. It has comparatively little red or hematitic ore. It is mingled rather confusedly with the greenstone, which appears in it in isolated and somewhat irregular areas, and also holds small nodules and fragments of the ore, which are as small as half an inch, or smaller. It appears from all that is known of this deposit that it is similar in structure to one of those described in sec. 16, T. 63-9, and to that seen in the south ridge at Tower, viz., that round about an indigenous jaspilyte lying in the greenstone of the Kawishiwin has accumulated a fragmental rock containing much debris from both of them, and that this coarse fragmental jaspilyte belongs to the basal conglomerate of the Upper Keewatin. By upheaval, shearing and pressure the two are thrown together in such confusion that their relations and sequence are not easily made out.

Further toward the northeast, about Ensign lake and thence northeastward to Knife lake and Otter Track lake, the distinctly greenstone characters of the Lower Keewatin fade out, and the clastic characters become more evident, constituting fine green argillytes, greenish flints and graywackes, and containing occasional jaspilyte deposits into which the greenish rock graduates across the bedding with many interchanges of composition. Such a jaspilyte is seen on the north side of Otter Track lake, also north of Pseudomesser lake on Hunter's island. It is probable that the north contact line of superposition of the Ogishke conglomerate on the Kawishiwin passes a mile or two south of the international boundary from Kekequabic lake to Oak lake (east of Otter Track lake), but the rocks of the region are very distinctly stratified, consist largely of argillyte and fine graywacke, and are much disturbed, striking in different directions, varying from northwest to northeast, and thus would have to be considered as belonging to the distinctly bedded portions of the Lower Keewatin.

Further west and southwest, and especially about Pine lake, in T. 64–10, the lowest greenstone manifests other variations. In the S. W. ¼ sec. 34, some drilling and shafting have been done with view to the discovery of

merchantable iron ore. The rock rises in the form of knobs from 50 to 150 feet above the valleys, and carries considerable fine jaspilitic silica without the appearance of much jaspilyte proper, so far as could be seen. The diamond-drill cores showed white "chalcedonic" silica. The rock in general has a fracture and structure like that at Kawawsachong falls, and contains pyrite, calcite, and apparently siderite, and is intersected by slickensided parting planes.

At the southwest corner of Pine lake is a display of agglomeratic greenstone. This is near the centre of sec. 34, T. 64-10, at the western end of a small island. Aside from the agglomeratic structure, which resembles that seen at Ely, the rock is amorphous, but is overlain by a basal conglomerate of the Upper Keewatin, the pebbles of which are of fine, flinty greenstone and of jaspilyte. These greenish and flinty pebbles are quite similar to rock seen in the Lower Keewatin in numerous places from Knife lake westward and southwestward. It is quite conspicuous about the south shores of the small lake crossed by the section line between secs. 22 and 27, T. 64–10 (Nos. 2161, 2162), known as Little Sucker lake. It is very siliceous, weathering nearly as light as a granite, fine-grained, gray-green within, fibroschistose, but not visibly laminated, rising in bold glaciated bosses. On the weathered surface it is pitted from the decay of some of the minerals. This rock seems to vary gradually, toward the west, to a massive greenstone which has irregularities of structure, and quartz veins, is schistose, but is not visibly laminated. This same siliceous, fine-grained rock (hardly a greenstone) is in several small islands that cross the lake in a line toward the west. This rock seems to be worthy of a name. It forms an important belt in the older greenstone at this place. It is neither greenstone, nor fine granite, nor quartzyte, nor flint, and it does not have the metamorphic origin ascribed to hornfels, but in many places it approaches nearest to flint. Under the action of metamorphism it would make a very dense and enduring rock.

Another variation in the older greenstones is to what has been styled, in Mr. Elftman's field-notes, "pepper rock," characterized by dark specks, caused by hornblende crystals, which is common about the eastern part of Pine lake (Nos. 2164, 2165). It is massive and apparently of igneous origin. But, owing to metamorphism and squeezing, much of the rock, which was originally clastic, has been so reconstructed, and at the same time forced amongst the surrounding masses, that it is frequently impossible to distinguish it from true igneous rock.

The Kawishiwin about Pine lake also embraces some jaspilyte, in unimportant amounts, lying in rock below the conglomerate seen at the southwest corner of the lake. Jaspilyte is in a rigid, green, coarse schist, S. E. ¼ N. E. ¼ sec. 34, whose structure runs with that of the country, about east and west, dips about 80° to the south. It is a low exposure on a small point, and has been explored a little. On the opposite side of the same bay, N. E. ¼ N. W. ¼ sec. 34, the same coarsely schistose greenstone is seen, dipping in the same way, but mainly more massive, rising to the hight of twenty feet, sloping from the water in a glaciated boss.

Near the section line, on the north side of sec. 34, T. 64–10, is a similar coarse, green rock, with a slatiness that is about vertical; but this varies on the north to a very fine flint, or flinty, gray-green slate (No. 2168), much jointed, so as to part easily into small rhomboidal fragments, and this rock may have furnished numerous pebbles for the overlying conglomerate, whose strike passes through the country east and west but a short distance further south. The immediate overlie of this conglomerate on the greenstone is seen indistinctly on the small island at the southwest end of Pine lake. Here the greenstone itself is not only agglomeratic, but is also spotted indistinctly and sparsely with forms that suggest a pebbly composition, the possibly pebbly forms being of a dense and compact texture, and slightly different from the matrix. Again, are seen irregularities showing a variation in the opposite direction, *i. e.*, coarser in grain than the matrix; and, while these coarser spots are noticeable, they are of irregular, often elongated, shapes, in the main. Only rarely does one appear to be rounded as by attrition. The rock, as a whole, is irregularly massive, *i. e.*, not laminated or bedded, but, on weathering, at the lake level, it develops a coarse lamination which is rough and rather lenticular, dipping southerly. Its comparatively rotted condition is the chief difficulty with considering it an original irruptive, while its association with jaspilyte, with siliceous gray slates and schists and flints, and occasional unmistakable evidences of fragmental accumulation, point strongly to a clastic origin. There is no known way by which a rock, originally basic and igneous, can be made to assume such forms. It seems reasonable to conclude that here the basal conglomerate of the Upper Keewatin lies on an older clastic rock of the Lower Keewatin. The determination that this greenstone (with its associated clastics) is the oldest known rock, will perhaps allow the assumption of conditions of sedimentation quite different from those that we know of at the present day.

On the south side of Jasper lake, sec. 2, T. 63-10, is a high ridge running northeast and southwest. In the S. W. ¼ S. W. ¼ jaspilyte is found in the lower part of the ridge, dipping about 75° S., running under the greenstone (No. 36E). Much of this ridge is composed of a coarse "pepper" rock, *i. e.*, sprinkled with hornblende crystals, which stand out on weathered surfaces, making a very rough aspect. This greenstone ridge runs eastward to the range line, and contains jaspilyte again at half a mile east of Jasper lake.

The older greenstone, therefore, appears, in the northern part of Lake county, to exist in the form of a two-forked area, the branches of the fork forming a rim of a basin which pitches toward the northeast, and has been folded upon itself. In this basin are included folded beds of the Upper Keewatin which lies on the greenstone rim, and exhibits a basal nonconformity along both sides of the basin. The most westerly appearance of this conglomerate is on the north shore of Saturday lake. About Ensign and Knife lakes are a lot of fine-grained clastic rocks which are classed with the Lower Keewatin. Here are frequent instances of fine or flinty, siliceous bands, alternating with and grading into jaspilytic bands and into argillyte, the jaspilyte appearing to be simply a phase of the finer sedimentation. Such is seen at the eastern end of the portage from Potato lake to Knife lake, where the slates and jaspilyte bands are in common bent and convoluted. Similar slates continue eastward to Mokoman island, where they stand on edge and strike N. 72° W. They split into very thin leaves—even a sixty-fourth part of an inch.

On Pickle lake, at the southwest corner N. E. ¼ N. W. ¼ sec. 35, south shore of the lake, is a hard green slate, with strike and cleavage N. 30° E. (mag.), vertical, and lamination apparently coinciding with this. South from the shore a few rods the same rock is seen interbedded minutely with dark red jaspilyte, the bands of jaspilyte varying from a sixteenth of an inch to two inches in width. Here the rock is much crumpled, and no general strike is discoverable (No. 772G). This rock is similar to the irony slates on the north side of Otter Track lake. This same rock extends along the south shore of this little bay. On the little point on the north side of the bay a hill is composed of hard, gray slate, sometimes greenish-gray. The strike of the cleavage is N. 60° E., crossing the crumplings of the strata.

Similar gray and greenish siliceous slate occurs about the west end of Epsilon lake, sec. 29, T. 65–6. In some part this is also a dark red jaspilyte. The slate here becomes very schistose and fissile, and resembles a sericite schist.

Further details of the greenstones that appear along the north side of the Kawishiwi river in T. 63–9 and 10 will be found in the description of the Gabbro lake plate (chapter xxi).

Note. In September, 1898, further examination was made of the greenstones west and southwest from Snowbank lake with a view to ascertain, if possible, the relation it bears to the porphyry, or porphyrel, of that region, and to the conglomerate mentioned above. The route of examination was from the Kawishiwi river to Triangle and Northwestern lakes and eastward from the latter to the great greenstone ridge, northwest corner sec. 16, T. 63–9 W.; thence northward to Moose lake, and eastward to Snowbank and Disappointment lakes, returning by way of Wood and Bassimenan lakes. Plate BB shows two views of greenstone on the Kawishiwi river.

In making a portage from the Kawishiwi river to Triangle lake, N. E. ¼ S. W. ¼ sec. 24, T. 63–10, the granite runs out soon, but it passes through a phase of schistosity in which red and green alternate in fine films of fine-grained rock (No. 2225), often running out. The red element prevails toward the south, and the green toward the north. The aspect is such as to suggest that the greenstone, which exists in full force further north, is here gradually converted into red granite, the nature of the greenstone having been that of a greenwacke with more siliceous ingredient toward the south. At the shore of the river the granite shows no abnormal features, but it incorporated fragments of the greenstone, as in an igneous intrusion (No. 2226). Between the finely laminated and the plainly fused or granitic rock is a belt, ten to twelve rods wide, of more coarsely laminated rock, the two sorts of rock blending into another intermediate phase, evidently not completely fluid, but plastic, more crystalline than the finely laminated rock, but less than the granite. So far as appearances in the field indicate, there is a perfect blending of the two rocks, the belt of transition being ten to twelve rods wide; the direction of the structures in the intermediate rock being the same as that of the mica schist next north, and the same as that of the greenstone still further north.

After a narrow belt of mica schist, which does not weather red although it is seamed and veined with impefectly developed granite in all directions, the real greenstone is encountered. This is also much seamed by white quartz of the jaspilyte kind, and is faulted and twisted in all manner of irregularity. It also shows the agglomeratic structure seen at Ely, and occasionally is slaty with jaspilitic silica.

It ought to be stated further, in the description of the foregoing finely laminated rock, that it is not evidently crystalline. The red portion is very fine or like felsyte, and the green is greenish-gray, fine-grained and siliceous. The whole transitional belt may be due to a shearing movement affecting the contacting portion of the granite, at the time of a true igneous intrusion on the greenstone.

The country thence northward to Triangle lake is occupied, so far as observed, only by greenstone. The same is true about the shores of Triangle and Northwestern lakes, and eastward to northwest corner of sec. 16, T. 63–9. At the section corner of sections 7, 8, 17 and 18 is to be noted an interesting fact, viz., rounded masses of white granite are in the greenstone, which in the immediate vicinity is also agglomeratic, though not in the portion immediately surrounding the granite pieces. There are ten or fifteen of these granite masses, varying from six inches downward. They lie in a rather granular greenstone, and are associated with some greenstone pebbles equally large. The area in which they lie is perhaps ten feet from one extreme to the other, but it is not in any regular way related to the surrounding greenstone, which is massive and seamed. There is no film of darker chloritic material surrounding the granitic masses, nor is there about the greenstone pebbles, yet the agglomeratic structure characterizes the greenstone at large, including the presence of the dark films.

It is plain here that there are two sources for these greenstone masses or pebbles, one agglomeratic, with the surrounding films, and the other conglomeratic, without them. It is possible that this may be a remnant of the basal conglomerate of the Upper Keewatin.

At the corner of secs. 8, 9, 16 and 17, T. 63–9, the ridge of "diabase" mentioned is fine and firm (No. 2227), and much of it is agglomeratic. This ridge slopes gradually (along the section line) toward the north, and at about 300 paces south of the quarter-post, east side of section 8, is succeeded by a greenstone conglomerate, derived apparently from this greenstone. Besides the greenstone pebbles, which may be referred to the agglomeratic portion of the greenstone, this conglomerate contains a few roundish fragments of white and red jaspilitic silica. This conglomerate is 105 feet in extent across the strike, and the structure is about vertical. It is succeeded northward by a light-weathering, quartz-orthoclase porphyritic rock, or porphyry, described in another place, which, in turn, is followed northwardly by another greenstone (plate Z, figures 1 and 2), which has a conglomeratic (?) base holding many pieces of this porphyry (Nos. 2230 and 2240). It hence appears that the second greenstone was separated from the oldest greenstone by an interval of time during which was produced, in some way, the porphyry (No. 2229). In the later greenstone there is, so far as seen, no agglomeratic structure, but that feature is common in the greenstone lying south of the porphyry.

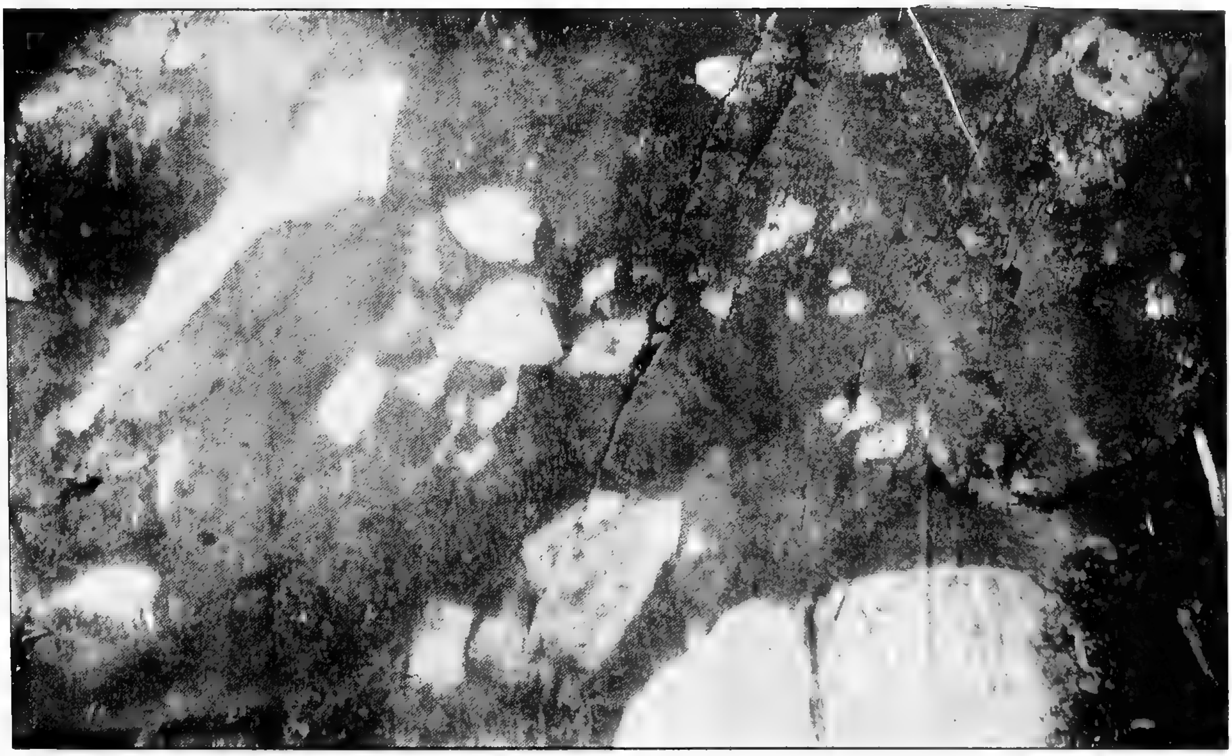


FIG. 1. NEAR VIEW OF THE GREENSTONE CONTAINING DETACHED MASSES OF QUARTZ-PORPHYRY (SEEN IN FIG. 2) SHOWING THE FINER DISSEMINATION OF THE SAME MATERIAL. (p. 276.)

FIG. 2. DETACHED PIECES OF PORPHYRY IN GREENSTONE, N. W. ¼ N. E. ¼ SEC. 8, 63-9. SOUTHWEST FROM SNOWBANK LAKE. (pp. 276, 292.)

[COMPARE PLATE W.]

FIG. 1. KAWASACHONG FALLS; ENTRANCE OF KAWISHIWI RIVER TO FALL LAKE, OVER GREENSTONE. (pp. 276, 400.)

FIG. 2. RAPIDS ON THE KAWISHIWI, OVER GREENSTONE. (p. 276.)

With a hand-glass it can be seen that in the later, or fragmental, greenstone the green hornblendes are roundish, and embraced in a mesh-work of the white element which seems to be silica. In some places this mesh-work stands above the rest of the rock and forms a sharp roughness. In the igneous greenstones the white element (feldspar) weathers away faster than the dark, and the prominences are of pyroxene, or of pyroxene and magnetite. In some parts of this later greenstone the grain is very fine, but usually with a hand-glass, on somewhat weathered surfaces, this relation between the hornblende and the white element can be seen with more or less distinctness. In examining a true igneous greenstone the white element is seen to have the form of plagioclase crystals, which enter independently into the darker element, making an ophitic structure. This is not everywhere observable in such rock, but the two elements are confusedly mixed; yet even an occasional instance of this structure is enough to show that the dark element crystallized later than the white, which is the reverse of the fact in the fragmental greenstone.

The line between secs. 4 and 5, T. 63-9, runs northward into a lake before reaching the town line, and at the shore of the lake is a deposit of jaspilyte in greenstone. Before reaching this jaspilyte, for several rods the interrupted rock exposure shows a fragmental greenstone, sometimes with fine pieces of jaspilyte disseminated thickly, and sometimes with variations in the greenstone itself, even to showing schistose bands of fine grain. At the same time throughout the whole mass is much fine silica, which makes a sharply rough weathered surface. There are also many veins of vitreous quartz (compare figure 2, plate WW).

Nearer the jaspilyte mass the greenstone becomes apparently pebbly, with siliceous variations of itself, and nearer still the siliceous element is more evenly distributed. In that way, with a coarser condition of the hornblendic element, is produced the rock which Elftman styled "pepper rock," the siliceous element constituting half or more of the actual contents and surrounding the hornblendes. It is in the midst of this rock that occurs the jaspilyte. Near the jaspilyte the hornblendes are sometimes over a quarter of an inch long.

The jaspilyte is abundantly interbedded with hornblendic rock material, such as has been described at Tower. The ore, so far as seen, is poor and of small amount, none being seen of merchantable quality. Occasionally even the siliceous element of the greenstone goes into these interlaminations along with the hornblendic. and the jaspilyte is actually banded with narrow, parallel belts of greenstone, the only difference between these bands and the regular greenstone mass being the slightly more siliceous nature of the bands and the coarser condition of the hornblendes.

Jaspilyte recurs again at the east end of this lake, where the greenstone is also cut by three red granitic dikes.

The rock immediately south from the jaspilyte mass is conglomeratic, and at the west it is agglomeratic, It appears that the conglomeratic portion consists of the central cores of the agglomeratic bombs, the rock being light-weathering greenstone in each, but in the former without the encircling dark films.

At a point further west, still on the south side of the same lake, is a gabbroid rock (No. 2247) in which apparently pyroxene and (magnetite?) exist, the latter being reddish and perhaps now having some of the alteration products of titaniferous magnetite. This rock, at one place at least, has a sharp contact on the schistose conglomeratic greenstone described above, and is plainly of later date than that greenstone. This rock may be compared with No. 2254.

Continuing along the bare, rocky ridge which bounds this lake on the south, there is to be observed much of the rock resembling gabbro (No. 2247), and of the coarse, massive greenstone which embraces the jaspilyte above. These rocks are closely intermixed, but in the field the gabbroid rock shows no important shearing effect, and in other respects seems to be later. The other becomes schistose and is cut by the gabbroid rock. In one the pyroxene crystals stand out on the weathered surface, causing the chief roughness; in the other the roughness appears to be due to a siliceous mesh which permeates the mass of the rock.

A similar gabbroid rock (No. 2254) cuts the basal conglomerate of the Upper Keewatin at the west end of a small lake lying near and north of the west end of this lake. In the vicinity are several drift boulders of gabbro whose source is not known, but which probably came from the north, and from similar dikes or bosses.

The Upper Keewatin, at this place, contains pebbles as follows, forming a coarse and conspicuous bluff near the little lake: greenstone, jaspilyte, fragments of the agglomeratic amygdaloid of the Lower Keewatin, slaty and flinty pieces from the slates and graywackes seen south of here, fine-grained porphyritic granitic rock (No. 2248).

Along the north side of still another little lake, S. E. ¼ sec. 32, T. 64-9, is a conspicuous hill in which is a great display of gabbroid rock (No. 2255), and it here apparently cuts older greenstone. It is fifty paces south of the quarter-post, between sections 32 and 33. It is amygdaloidal, in narrow belts, the fillings being pinkish white, hard and coarsely radiated, as large as peas, and apparently a zeolite. It is evident that this greenstone is fresher than any of the Kawishiwin greenstones, and also that is later than the Upper Keewatin, which it cuts. It forms the chief topographic outlines for a quarter of a mile, continuing for some distance north of the above mentioned quarter-post, in a very rough country, the main ridges running north of east (No. 2258), but the next sharp ridge, whose summit is 250 paces north of the same quarter-post, is composed of agglomeratic greenstone. It is precipitous, both to the south and to the north, and about 150 feet above the adjacent valleys.

The next ridge is composed of greenstone conglomerate, with some pebbles of jaspilyte, and some of a rock much resembling Nos. 2255 and 2258. The great bulk of the conglomerate consists of fine-grained siliceous greenstone which may have come from the agglomeratic masses of the older greenstone. It is largely cemented by quartz. Toward the north this graduates into finer conglomerate (No. 2259) and to graywacke, interbedded with coarser conglomerate. On crossing a subordinate valley the next ridge is found to be of graywacke and greenish graywacke, but toward the north this ridge is porphyritic with white feldspars (No. 2260), which are

sprinkled over the weathered. The rock remains green, or grayish green, but the feldspars weather a little pink. They are more numerous in some places than in others, and, indeed, there are small areas in which a rude banding, somewhat like that of stratification, can be seen. Throughout this rock are foreign pieces, either of jaspilyte or of greenstone, and a micaceous darker rock, a mica-porphyry, occurs suddenly, running like a dike (No. 2261).

In some places this green porphyritic rock (No. 2260) holds jaspilyte pieces six inches across. Where it is in contact with the slates and graywacke there is a band of a couple of feet in which the two rocks mix. Sometimes the porphyry is really a greenstone, with only very rare evident crystals (No. 2262). It seems not only to be in contact with the slate and graywacke, cutting them as an igneous rock, but also has a kind of alternation with them, as if a member of the same sedimentary series. This alternation is hard to understand, but in view of the zigzag fracture and intense squeezing it may be these alternations are due to mechanical fracture followed by pressure, as well as to the inclusion of slate in the porphyry in the act of intrusion. There are numerous bits of slate and jaspilyte in this green porphyry, but the rock is mainly massive and uniform; the schistosity can be attributed to fracture and movement.

Along the section line between secs. 32 and 33, and between secs. 28 and 29, T. 64-9, the structure seems to consist of a succession of short ridges formed primarily by folding, the geological horizon gradually ascending toward the north. The most of the rocks dip nearly vertical, or slightly to the south. The last rock at the shore of Moose lake is a conglomerate much resembling some parts of the Stuntz conglomerate, but finer, the pebbles derived apparently from some porphyry belonging in the Lower Keewatin, but now folded, along with the Lower Keewatin greenstones, closely with the Upper Keewatin. The mechanical contacts of the porphyry on its own debris, formed by such folding, are difficult to distinguish from true igneous intrusion, and hence some of this porphyry may not belong to the Lower Keewatin, although there is no proof to the contrary.

The island in Moose lake crossed by the section line between secs. 28 and 29, T. 64-9, is composed largely of an irony sericitic schist, cut by a rather fresh diabase dike four feet wide, and by a narrow vein-like quartzose dike of fine red granite. This schist (No. 2270) is bright green at the summit of the island toward the northeast end, and is charged with carbonate of iron, which oxidizes but does not stain the weathered surface. This bright green or bluish green color, however, fades out in other places, and the surface is more or less rusty, the interior being gray. In this rock is much pyrite, evidently cupriferous, since the schist is stained by malachite green at a little depth, in scattered small points. Most of the island is outwardly composed of fissile, rusty sericitic schist standing vertical, but along the south shore is a fine slaty argillyte.

Westward from the jaspilyte locality, on the trail from Moose lake to Wood lake, is found a series of ridges of the Upper Keewatin. Some are of conglomerate and some of schist. The last ridge, near which the trail passes, is the highest. The rock of this ridge illustrates the close folding and shearing to which much of this region has been subjected. The rock weathers light blue, or greenish, but does not belong to the greenstones of the Lower Keewatin. It consisted originally of banded, fine slate and fine graywacke, but it is broken into a series of short parts in a manner like that illustrated at Cloquet (figures 1 and 2, plate Y Y), in Carlton county. Hence, on the weathered upper surface it appears somewhat like a sheared, or pressed, conglomerate, consisting of only two sorts of rock. On weathered vertical surfaces, however, the separate parts, which might be mistaken for detrital pebbles, are seen to descend far down into the mass lenticularly.

On the trail from Moose lake to Flask lake, there occur two greenstone ridges, which can be referred to the Lower Keewatin, the intervening ridges belonging probably to the Upper Keewatin. One of these old greenstone ridges is about one-third of the way to Flask lake, and the other is near that lake. Granitic rock and granite porphyry cut the former. The last rock seen toward the east is a fine schist.

East of Flask lake the rock is distinctly greenstone, rather firm and often hornblendic, like No. 2267, but toward Snowbank lake it becomes more and more conglomeratic, as seen at the west shore of that lake. It is hard, greenish, massive, and blotched with epidote seams and veins. This rock is included in the Upper Keewatin. It is that cut by the Snowbank lake granite.

(2). Evident clastics and iron ores. Allusion has been made to the Upper Keewatin, as distinct from the Lower by reason of the coarse basal conglomerate that marks the commencement of the former. It is in this conglomerate that occur the iron ore deposits here referred to. The conglomerate is a very extensive part of the Upper Keewatin, and can be identified from Saganaga lake to Saturday lake, but iron ore has been found indigenous in it at but one place.

This iron ore is not known to be different from that already described in the Lower Keewatin, in any other respect than that it is at a higher stratigraphic horizon, and is the matrix rock of a coarse conglomerate. They are both banded jaspilyte. This locality is on the portage trail from Moose lake to Wood lake, but near Moose lake; west side of sec. 21, T. 64-9.

Fig. 1. Bouldery and Pebbly Jaspilyte, near Moose Lake, West Side Sec. 21, 64-9. The Large Form at the Centre is Granite. (p. 279.)

Fig. 2. Same as Fig. 1. (p. 279.)

The country is burnt off (August, 1897) and the rock is bare, showing its structure. There is a series of north-northeast and south-southwest ridges crossing the country parallel to the direction of the lake and of the islands, and on the portage trail they are quite conspicuous. At the lake is schist, quite fissile, as seen on some of the islands and the points, and argillyte, often green and falling down in large slabs, probably suitable for roofing slate. Immediately north of the portage landing rises a very singular and interesting ridge, which is steep on the south side and slants with the dip, and is somewhat more gradual on the north. The dip is 80° or 85° toward the south. This ridge is made up of conglomerate, in general, but shows interesting combinations:

1. It contains considerable deposits of jaspilyte, normal in all essential characters, rather magnetitic than hematitic, but considerably contorted and varying to a greenish siliceous jaspilyte, and to dark slate.

2. This jaspilyte embraces rocks of different kinds, as pebbles, and even occasionally as boulders, the bands of the jaspilyte swinging round and embracing them when large. The enclosed stones are of different sorts, but red granitic rock prevails. Such red granitic rock is also the prevalent pebble throughout. Greenstone pebbles, hard, siliceous, green, flinty pebbles, and apparently pebbles of jaspilyte, which is fiery red in color, are also included in the jaspilyte.* Yet in the main, it is simply a banded jaspilyte nearly free from pebbles. The largest granite boulder seen is about ten inches in diameter. This jaspilyte is indigenous in the formation and its layers are frequently separated by fine green sediment, and sometimes by a coarser gritty green sediment. When the interleaved sediment is fine and greenish, it is also very siliceous, making a greenish flint. A bouldery portion of this jaspilyte is represented by figures 1 and 2, plate X.

3. The conglomerate, in its southern portion, is characterized by a red-weathering granite, but it also contains greenstone and jaspilyte and a siliceous, very fine rock, like flint.

4. The jaspilyte itself occurs not only as large masses, but is strung out in small lenticular thin sheets throughout the southern part of the conglomerate; and it fades out sometimes across the bedding into the general conglomerate, passing through a stage of siliceous, black or greenish slate (No. 2274).

5. Aside from the twisted and confused condition, there is nothing further worthy of note in the southern belt, which is about thirty feet across.

On the south the rock, while plainly a part of the fragmental series, is of a coarse, irregular green schist, containing much vitreous quartz in veins running with the schist. This is visible only at the west end of the ridge. There is also some such quartz in irregular deposits throughout this conglomerate.

6. On the north side, while the conglomerate is continued in that direction, yet it consists wholly of greenstone debris, and is so consolidated that it looks like the massive greenstone of the Lower Keewatin. In some places it is so fine-grained, massive and uniform that it looks like some conditions of the agglomeratic greenstone.

7. The importance of this observation consists in showing conditions that attended the origin of the jaspilyte with its irony ingredient, cotemporary with a fragmental accumulation, and due to a force (oceanic water), the same as that which accumulated the conglomerate itself. That it is so fine can be explained on the precipitation theory.

Another ridge further north, according to Mr. Elftman, is of conglomerate, with pebbles of red granite, greenstone and jaspilyte. This is 300 feet from the foregoing. The entire thickness of the conglomerate at this place is about 600 feet. The third ridge still further north consists of firm, compact, much-sheared green schist and graywacke, supposed to belong to the Upper Keewatin, as already described. There is another jaspilyte belt north of the one described, having a width of about thirty or forty feet, making a total thickness of about 100 feet of jaspilyte in 600 feet of conglomerate.

The great Ogishke conglomerate, which here contains this ore, is a conspicuous formation all the way from Saturday lake to Saganaga lake. It is worthy of note that in 1887 Dr. A. Winchell published a note of a similar occurrence of jaspilyte in this conglomerate near Ogishke Muncie lake, as follows:† "Ogishke conglomerate, pretty well developed. Contains red jasper, not as a pebble, and this is banded and associated with hematite (No. 886W)."

This conglomerate is in nearly all places quite coarse, but it shades sometimes into graywacke, and the graywacke becomes argillyte. One of its greatest peculiarities is its porphyritic aspect, arising from the abundant dissemination of feldspar crystals. In several of the annual reports these feldspars have been considered as

*A more careful enumeration of the sorts of rock represented in this conglomerate was made in September, 1898, viz..

1. Dark-weathering greenstone, rounded, one piece being twenty inches in longer diameter.
2. Red fine-grained granite, weathering pink.
3. Brick-red jasper, in angular fragments, sometimes in the bands of jaspilyte.
4. Porphyry, not quartziferous, twenty inches in diameter; rounded, also very fine; abundant.
5. Light-weathering greenstone.
6. Hard felsyte, light green.
7. Dioryte, with rather coarse hornblendes.
8. Pinkish, fine-grained, apparently granitic rock, with phenocrysts of hornblende, very common in the ridge next west. (This may be the same as the red granite, No. 2.)

The brick-red jasper pieces are confined to the conglomerate in the near vicinity of the main jaspilyte mass, which suggests that they may all be referred to displacement from their parent mass in the conglomerate by folding and shearing, and that hence they may not indicate an earlier jaspilyte.

† *Sixteenth Annual Report*, p. 315, 1888.

of secondary origin, due to metamorphic agencies, developed since the consolidation of the rock. These crystals are not always angular and entire, but as fragments they are reduced in size and blend with other debris to form the general matrix of the rock. Such pseudo-porphyritic rock was named *porphyrel* by Dr. A. Winchell, in the fifteenth annual report,* a name which seems appropriate and necessary. Several petrographical descriptions of this rock from the vicinity of Kekequabic, Moose, Zeta and Ogishke Muncie lakes are given elsewhere (Nos. 1062, 1094, 2170). What may have been the source of these feldspar crystals is still a subject of inquiry. There were, as appears from the field observations, many dikes, and perhaps considerable areas, of porphyry, very similar to this rock, and of porphyritic granite like that of Iron lake, cutting the Lower Keewatin, and, on disintegration in the ocean of the age of the Upper Keewatin, such crystals may have been disengaged in great numbers. As these crystals, however, are associated with augite crystals (usually much altered to hornblende), and as the rock seems to grade into a rock which is essentially a submarine tuff having more or less of ordinary detrital character, it is perhaps more likely that in some cases the crystals were ejected from volcanic craters of the date of the Upper Keewatin.

This rock has attracted a great deal of attention from all members of the survey. This is owing to its bold and frequent exposures, its great extent and its variations in composition, and to a powerful metamorphism which it has suffered, causing it to take on the aspect of a dense mica schist, and even to act apparently the rôle of an intrusive amongst the associated strata. These intrusive characters are considered under the following heading: *Igneous rocks of the Keewatin.*

At Saturday lake. The most western known appearance of this conglomerate in Lake county is on the western shores of Saturday lake. On the south side, at S. W. ¼ N. E. ¼ sec. 36, T. 64-11, near the portage landing from Fall lake, is an argillitic and chloritic condition of this conglomerate (Nos. 175W and 2145). The rock is completely beset with pebbles, mostly less than three inches, but some are stones six to ten inches, in diameter, weathering lighter colored than the matrix and having a finer grain (No. 2145A). On fresh fracture the pebbles are greenish and blend with the rock so as to be almost indistinguishable. They are hard and weather nearly white. The schistose structure runs N. 45° E., and the pebbles have a prevailing parallelism with the schistosity. They appear like flint and sometimes have an older fine jointing or structure resembling slatiness, which does not agree with the schistosity of the rock.

A light weathering belt, somewhat in the form of a dike, cuts the little knob composed mainly of this conglomerate, nearly, but not quite, parallel with its schistosity. It is a straggling dike and is very fine-grained, with a fine schistosity parallel with that of the rock. The green schist lying a little further south stands nearly vertical, and much resembles the green schist seen along the south shore of Fall lake (Nos. 2147 and 2148). A low bluff, S. W. ¼ N. E. ¼ sec. 36, T. 64-11, consists of a more uniform greenstone, not showing sedimentary structure, but holding irregular light-colored siliceous masses, curiously shaped. This rock (No. 2148) resembles the rock at Ely, even to the amygdaloidal porosity; but here, instead of having bomb-like forms with calcite in peripheral cavities, such cavities are generally distributed in the rock, and, on weathering, such cavities are quite marked. This schist and greenstone, therefore, are a part of the Lower Keewatin, and the line of transition from Lower to Upper is between this and the foregoing conglomerate knob.

On the north side of Saturday lake the basal conglomerate appears conspicuously at the shore, forming a range of low hills for half a mile in N. E. ¼ N. E. ¼ sec. 36, T. 64-11. Here the rock is very schistose, and yet it has, as at No. 2145, veins of vitreous silica. Frequently a whitened, weathered surface presents much the aspect of the Stuntz conglomerate, but in general here the matrix is much more green.

At Pine lake. From Saturday lake the strike of the northern border of the conglomerate is nearly eastward, to the southwest corner of Pine lake, where it appears on a small island, as already mentioned, and in the

* *Op. cit.* p. 159, 1886 [1887].

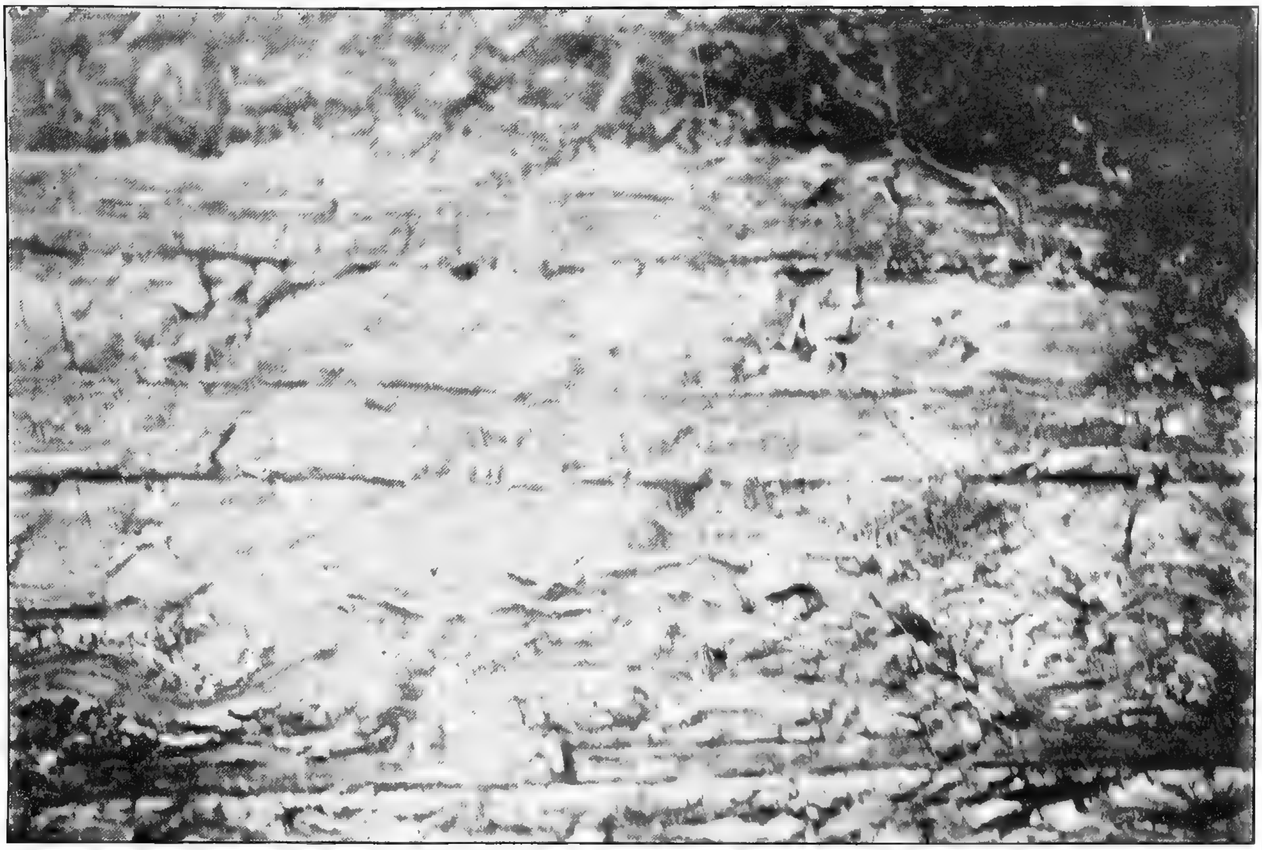


FIG. 1. CRUMPLED LAYERS EMBRACED BETWEEN UNCRUMPLED, NEAR FOX LAKE, ON THE PORTAGE TRAIL TO AGAMOK LAKE. (p. 281.)

FIG. 2. BASALTIC STRUCTURE ASSUMED BY GRAYWACKE AND SLATE, EAST END OF EPSILON LAKE, T. 65-6. (p. 282.)

same manner is immediately above a fragmental greenstone. At the centre of sec. 34, T. 64–10, Pine lake, it contains pebbles of jaspilyte and siliceous greenstone. It rises as a glaciated dome directly from the water. The structure, dip, strike, etc., cannot be made out, but a general elongation of the pebbles, and the frequency of short seams, indicate a strike about east and west. The western part of the island mentioned consists of amorphous and agglomeratic greenstone, and the eastern is of conglomerate, and contains pebbles of fine and siliceous greenstone and of jaspilyte. The greenstone end of the island rises highest. The green siliceous pebbles of the conglomerate are like some flinty portions of the Lower Keewatin, which is well known, and occurs about Little Sucker lake, about a mile further north.

At Jasper lake, and in general through the northwestern portion of T. 63-9 W., wherever this conglomerate is seen, it is frequently charged with pebbles and sometimes with large masses of jaspilyte. These masses are so large sometimes that they appear to be *in situ*. In the same region are numerous knobs of indigenous jaspilyte, lying in greenstone, and these have supplied the debris of the conglomerate, whether it be of the green element from the Lower Keewatin, or of the jaspilyte. The formation here has resumed its strike toward the northeast. It appears on both sides of Moose lake, and forms a prominent part of the high ridge which runs along the east side of Moose lake. It occupies, however, in general, lower tracts than the underlying greenstone.

At and near Moose lake, on the line between secs. 32 and 29, T. 64–9, east of Moose lake, about a quarter of a mile from the lake, this formation appears at about 100 feet above Moose lake. It has a strike a little south of west, and stands nearly vertical, yet dips toward the south. The rock varies from graywacke to conglomerate. A schistose structure runs northeast, parallel with the direction of the lake. At numerous places in the graywacke, which is interbedded with conglomerate and with greenish slate, the hard rock is well preserved and exhibits glacial striæ. At the top of the hill this graywacke is coarse and rough. A large layer, running conformably with the strike, contains may elongated pieces of slate, like the slate interbedded with the formation; and in some places such fine slaty material is apparently in fine fragments mixed with the coarse grit. The graywacke also embraces pebbles of graywacke like itself, but either coarser or finer, so that their forms are distinct on the weathered surfaces. Sometimes, alongside of a graywacke layer containing such large fragments and small bits of rock like the rock of the formation, and even along both sides, can be seen unbroken strata of fine slaty material running parallel to each other. If the detached pieces of slate were included by brecciation in the coarser grit strata, why were not these straight beds also broken up? On the contrary the stratification in the main is rigid and continuous for rods. Some instances of squeezing and folding, and the thrusting of one layer into another, are observable here, but on a smaller scale than described on sec. 20, T. 62–15 W. (at Vermilion lake); but usually such derangements can be seen to be due to folding, and are, moreover, not common. Such folding can hardly account for the dissemination of these pieces, unless accompanied by brecciation and shearing. The phenomena here are somewhat like those which accompany the intrusion of a molten rock, and the incorporation of particles from the walls (see plate Y, figure 1). Yet the nature of the rock which appears to be a part of the conglomerate of the Upper Keewatin, and which is pebbly like a conglomerate, decidedly opposes the idea of the igneous origin of this rock. This is an anomalous condition of observed facts respecting this conglomerate, but, as will appear further, it is not an isolated case (rocks Nos. 2169–72; compare the chapter devoted to the Carlton plate).

In closely examining the alternations in the strata of the conglomerate, and searching for the place of superposition on the greenstone, it appears that there is a greater or less thickness of debris from the greenstone which, recomposed and sometimes hardened by metamorphosing pressure, appears like the greenstone itself, but is in places plainly made up of small imperfectly rounded fragments, which were not far transported from their native places. The conglomerate all along here dips toward the south, *i. e.*, toward a greenstone range, at an angle of about 85°. This is a part of the main greenstone belt of the region, and in general may be said to extend to the Kawishiwi river.

On the trail from Moose lake to Flask lake, this conglomerate appears conspicuously, the trail passing across the strike of the bedding. The country is sometimes hilly, and is favorable for careful examination. The rock in several instances was noted to be very similar to the Stuntz conglomerate, but most of it is a porphyritic conglomerate or porphyrel, the crystals being of detrital origin (No. 2184). At the same time in places it looks much like an igneous rock, and especially in the near vicinity of Snowbank lake, where metamorphism is more intense (No. 2185). Several low ridges of porphyry *in situ* occur in the midst of the conglomerate between Moose and Flask lakes.

As this conglomerate about the shores of Snowbank and Disappointment is largely changed by metamorphism, it will be considered in connection with the mica schists and igneous rocks of the Keewatin. Not much is known of the clastic rocks of the Upper Keewatin between Snowbank and Kekequabic lakes, but at the latter place they appear under various phases, and they are described in detail by Dr. Grant, in chapter xxiii, Fraser Lake plate, especially in their igneous characters. Here, also, however, there is a blending of igneous and clastic characters in the same rock, and some of the conglomerate is so altered that it appears like granite, although still showing numerous boulder forms. In less modified form this conglomerate is to be seen at Zeta lake.

Zeta lake is at the centre of sec. 28, T. 65–6, lying between Kekequabic and Ogishke Muncie lakes. It is, therefore, at such a distance from the granitic centre of the former that it is free, or nearly free, from the metamorphosing effects radiating from that granite, but it is, yet, not so far that the rock takes on the plainly clastic characters exhibited by this conglomerate at the latter lake. The name porphyrel was given to this conglomerate at this place by Dr. A. Winchell.* At the narrows of this lake, S. E. ¼ N. E. ¼ sec. 28, T. 65–6, is a characteristic appearance of this conglomerate (Nos. 1062, 1769, 1770). It is firm and rises in hills from fifty to seventy-

* *Fifteenth Annual Report*, pp. 158, 159, 1886 [1887].

five feet high. Blocks having a sharp, almost a basaltic jointage, fall down and lie along the beach. This basaltic structure in graywacke and slate at Epsilon lake is shown by figure 2, plate Y. It is plainly, at first, porphyritic, the feldspars being most numerous in some of the pebbles, but also distributed throughout the green matrix, and also conglomeratic, the pebbles consisting of porphyry and of greenstone. It has no schistose structure, but shows occasionally a linear distribution of parts which is like a sedimentary banding. Hornblende crystals are perhaps as numerous in the rock as those of feldspar, but are not so conspicuous. The occasional pebbles have undergone a partial re-crystallization and are blended with the matrix, so that their outlines are not distinctly defined, but the existence and the size of the pebble are now indicated by the greater or less frequency of the light feldspar crystals. The greenstone pebbles, which are distinctly rounded, are not at all porphyritic, and cause dark spots over the surface freshly broken. The rock was fragmental originally, but is now compacted and partially re-crystallized by metamorphism.

The porphyry pebbles in this rock indicate the prior existence of a rock in considerable amount capable of supplying them, and it is likely that all the clastic feldspar crystals of this rock came from the same source.

Ogishke Muncie lake. It has not been possible to separate this rock from the great conglomerate seen about Ogishke Muncie lake, either geographically or petrographically.

Indeed, sometimes a rock of the same character is seen at Ogishke Muncie lake (No. 1080). It was specially noted and collected at S. E. ¼ sec. 22, T. 65-6, where the crystals are somewhat rounded and disseminated through a coarse granular matrix in which are numerous rounded grains of quartz of about the same size, some fine red jasper, pebbles of greenstone, and of flint. About Ogishke Muncie lake the shores in nearly all parts consist of this conglomerate, but the northeastern shores consist of the fragmental parts of the Lower Keewatin. A collection of various pebbles from this conglomerate was made near the centre of sec. 23, T. 65-6, viz.: flint, from gray to black, like that seen about Knife lake, varying to siliceous argillyte; a quartzyte which is almost as fine as flint, but has a tendency to turn red; granitic porphyry, or simply porphyry, capable of furnishing many feldspar crystals on disintegration; fiery red jasper; banded jaspilyte; diabase; quartz; granite, with coarse quartzes like that of Saganaga lake; gray, banded quartzyte; fine-grained, greenish-gray porphyryte or dioryte; greenstone, without quartz, rather coarse and resembling the gabbro of the Knife lake headland, etc., sec. 22, T. 65-7, and N. W. ¼ N. W. ¼ sec. 29, T. 65-6; diabase with porphyritic plagioclase altered to "huronite," like rock No. 798aG; greenstone, fine-grained, gray; vein quartz, loosely open and mingled with epidote; fine, flesh-red granite, or aplyte, rusty, spongy vein quartz; quartz dioryte, or gabbro, like the rock of the headland (sec. 22, T. 65-7).

Dr. A. Winchell made the following enumeration of pebbles in this conglomerate on Camper's island, in Ogishke Muncie lake:* "Without attempting a complete enumeration, the following may be named: (1) syenyte, resembling saganaga syenyte, but with little hornblende; (2) greenstone; (3) porphyry; (4) red jasper; (5) flint; (6) quartz, opaque, white; (7) petrosilex; (8) ordinary syenyte with black hornblende; (9) dioryte, coarse, with dark-green hornblende; (10) dioryte, fine, with dark-green hornblende; (11) porphyroid, weathering light and cellular; (12) siliceous schist; (13) carbonaceous, siliceous argillyte—sparingly."

Along the south side of Ogishke Muncie lake the base of this conglomerate can be seen in unconformable superposition on the Lower Keewatin, as figured in chapter xxiii (Fraser Lake plate). It here frequently contains large rounded boulders of greenstone. It ascends well up on the northern slopes of the Twin peaks and in places becomes more siliceous, resembling the Stuntz conglomerate, and hardly distinguishable from a quartz porphyry (Nos. 1754–5). It has here suffered great compression, and, while plainly a conglomerate, viewed at large, when examined in hand specimens it would be classed as an igneous rock of the quartz-porphyry group, a statement which seems to be true of the coarser beds of the Upper Keewatin in many places.

At Saganaga lake. This conglomerate lies upon the Saganaga lake granite and is well seen, in its obscure clastic characters, at the portage between Oak lake and Saganaga lake (Nos. 2031 and 2032). Further toward the northeast it is much coarser, and, according to Dr. Lawson, on the north shore of Saganaga lake it contains numerous very large boulders of the granite, making a conspicuous display. In the vicinity of Oak lake, however, it is very fine-grained, and consists wholly of recemented debris of the granite itself. It thus resembles the granite proper, and as such it has been described by every geologist who has noted it on this portage. A little examination, however, toward the east, and on the shores of the bay running south, is enough to convince the observer of its true nature. As a rock it is light-colored. It lacks the ferro-magnesian minerals, and in that fact it differs from the true granite microscopically, while in thin section its fragmental structure is most evident. It is strictly a graywacke, and it is seen to be interbedded with slate along the shores of the bay in sec. 24, T. 66-6 W., although its lowest portions, including a thickness of several hundred feet, show so little variation by sedimentary action that it appears to be a massive granite. Some detailed descriptions are included in the twenty-fourth annual report. The conglomeratic composition appears higher in the series. This fine and non-stratified condition of the bottom of this conglomerate apparently is widespread, and when it comes upon the older greenstones the resultant clastic rock is hardly distinguishable from the parent rock. This renders it almost impossible to trace out the boundary line of superposition of the Upper Keewatin on the Lower.

(3). Mica schists. There are distinctly two sorts of mica schist within the limits of the county, viz., that produced by the granitic intrusion upon the Upper Keewatin, and that resulting from the contact of the gabbro.

* *Sixteenth Report*, p. 347.

Under the action of the granitic metamorphism there is a widespread hardening of the clastics, with the generation of biotite mica and secondary feldspar. These schists, as seen about Snowbank lake, are very firm, and aside from their conglomeratic composition are rather fine-grained and dense, usually having a strong and persistent schistosity, and compose some of the hills and prominent ridges of the region. The gabbro produces a rock which is also charged with biotite mica, but is characterized in the field with less firmness, and indeed frequently crumbles rather easily. The biotite here is sometimes in idiomorphic forms. This rock, within the area of this plate, has a close relationship with the rock called muscovadyte, into which it grades imperceptibly, and as such it embraces the iron ore seen at the south side of Disappointment lake. It appears that the rather loose and more friable condition of this schist is due to the other minerals which are found in it, and these other minerals are again due to the nature of the original rock before metamorphism. It is the greenstone band of the Archean which gives origin to these schists, and especially the clastic portions of the greenstones. They are typically seen about the shores and bluffs of the Kawishiwi river in sec. 16, T. 63-9. The differences of weathering between these schists are caused by the different amounts of quartz and of feldspathic ingredients. These minerals abound in the former, and are sometimes wholly wanting in the latter. When quartz becomes abundant in the latter it is in connection with the occurrence of some of the jaspilyte ore deposits, and the metamorphism of all the adjoining rock presents several very interesting petrographic features, which are detailed in the chapter on the *Petrographic Geology* of the northern part of the state (Nos. 2197-2203). In general it may be said that the resultant rock contains minerals secondary after those found in the greenstones, but associated with each other in a different order of generation, and in addition is found much hypersthene which frequently was the last to take its place, and embraces the other minerals poikilitically. Quartz and magnetite in varying amounts, sometimes composing nearly the whole rock, mark the jaspilyte horizons.

An extensive belt of mica schist and micaceous gneiss, varying to hornblendic greenstones, extends across T. 64-11, northeastwardly, and southeastwardly across T. 64-10, turning northeastwardly again and running in a narrower belt across T. 64-9 to the vicinity of Prairie portage. This area forms a border about the granitic boss of Bassimenan lake, which is intrusive into it in many places in the form of dikes, and is the result of metamorphism of the Lower Keewatin. It is also largely hornblendic. It occurs on the islands and shores of that lake. It fades out geographically into sericitic schists and into argillytes of the Lower Keewatin, when derived from the acid clastics of that formation, and into the massive and fragmental greenstones, when from the lower beds. These lower beds seem to be re-crystallized *in situ* on a large scale when affected by the zones of deep-seated regional metamorphism, becoming simply massive greenstones, but when in the immediate contact zone they are converted very largely into hornblende schists.

The mica schists produced by the Snowbank lake granitic boss are almost uniformly conglomeratic, having been formed by the metaphorism of the Ogishke conglomerate and related rocks of the Upper Keewatin, The large, round peninsula on which is located the corner post of secs. 26, 27, 34 and 35, T. 64-9 consists of a dense micaceous rock (No. 2185), more or less cut by dikes of granite. It has a distinct conglomeratic structure, and traces of the original sedimentary bedding. It strikes in the same direction as the general coast line, and parallel with the conglomerate further west (in sections 34 and 27) and the same as that in section 26. It dips

nearly vertical, like all the rocks of the region. The rock at the centre of sec. 26, and westward along the bay, is a "porphyritic" kind of conglomerate, or porphyrel, the feldspars being simply fragments of crystals, so far as they appear in the matrix, but larger in some constituent porphyry pebbles (Nos. 2186 and 2187). This is not markedly micaceous, but at a quarter of a mile further northeast, *i. e.*, S. W. ¼ N. E. ¼ sec. 26, T. 64–9, mica schist is at the shore of the lake (No. 2188). It is here cut by large dikes of granite, as well as by porphyry (No. 2189), the granite cutting the porphyry, a series of facts which is considered later under the topic *Igneous rocks*. The characters of the conglomerate about Snowbank lake and about Disappointment lake vary from mica schist, where the rock was fine-grained at first, to a conglomerate and a conglomeratic mica schist, or to a porphyry which acts the part of an intrusive on the mica schist, the intrusive rock not being separable either in the field or under the microscope from the porphyritic conglomerate.

Disappointment lake. The large point in the southern part of sec. 33, T. 64–8, Disappointment lake, consists of hard, sub-crystalline, massive conglomerate, supposed to be Upper Keewatin, in which are a few hornblendes, but scarcely visible mica schist characters. Westwardly, to the line between secs. 32 and 33, T. 64–8, the rocks were bare at the time examined, and the conglomeratic character is evident, the strike being irregular, but mainly east-northeast. There are some granitic dikes and also some basic, the former, in one instance, cutting the latter, the rock showing an increasing tendency to veining characteristic of mica schist—such fine veins as cross each other but hardly make anything but a coarse mesh-work in the rock itself, and appear on weathered surfaces. The rock becomes reddened in small areas, both by the existence of boulders and by splashes, as it were, of incipient granite of irregular shapes. In the main, however, the formation is dark-colored, micaceous and hornblendic (Nos. 2205 and 2206). All along the west shores of the lake the rock is decidedly micaceous and decidedly conglomeratic.

Near the centre of sec. 32, T. 64–8, west shore of Disappointment lake, a little southeast from the centre, the mica schist is conglomeratic, having a semi-granitic aspect. It is here cut by many dikes of red granite, and also *contains pebbles of red granite.* It can hardly be called mica schist here, although denominated so in the field notes of H. V. Winchell and A. H. Elftman. It is a very siliceous rock, probably a part of the same general formation, made up of debris of granite, quartzose rocks, and perhaps of quartz porphyry, and was originally, when fine-grained, a graywacke.

On the Kawishiwi river. There is a narrow belt of mica schist, belonging to the Lower Keewatin, extending eastward along the north side of the Kawishiwi, the continuation of that seen at "Silver City," at the north end of White Iron lake. So far as it extends into T. 63–10 it is described and mapped in the chapter devoted to Gabbro Lake plate, chapter xxi. In the next town west it is encroached on more narrowly by the distinctively massive greenstones of the Lower Keewatin, and the metamorphic effect of the adjoining granite is not to produce mica schist, but to recrystallize the greenstone itself. However, mica schist appears through sections 27 and 34 on the shores of Farm lake, in sections 35 and 26, at the latter becoming somewhat graywackenitic, while in section 25 mica schist and graywacke schist are interbedded, the latter containing much feldspar in many distinct grains with undefined outlines.

The first appearance of the second (mentioned) sort of mica schist is near the gabbro margin on the Kawishiwi river, sec. 19, T. 63–9. The rock here is a firm, tough, dark-colored, aphanitic and quartzless one which weathers red in some places. It is crossed by many veins or thin seams which, being harder than the adjacent rock, causing sharp ridges on the surface, which cross and reticulate with each other, cause the rock to appear like a cemented breccia, the parts not much displaced from each other. Some open spots have lost weathered-out fragments that were softer. There is a general gneissic, perpendicular structure that runs east and west. This is on an island that rises about four feet above the summer stage of the river, and the characters of the rock hardly illustrate the mica schist seen at the gabbro contacts; yet quite near this island is another, further south, which is composed of a biotitic gneiss, and such rock continues for a mile and more eastward, when it gives place to a more distinctly micaceous schist.

About the north ends of the northeast and southwest lakes through which the river flows in secs. 15 and 16, T. 63–9, is an interesting series of exposures, repeating some of the phenomena seen in section 19 of the same town. The old greenstone formation is here altered by the gabbro so as to form a twisted and broken gneissic, but sometimes heavy bedded rock, dipping in the same direction as the gabbro, and passing gradually into the gabbro, through a stage which is biotitic and pyroxenic (Nos. 982–4) and which has received the name muscovadyte. The older rock, as has been stated, sometimes consisted of more or less siliceous graywackes and schists, and sometimes was largely composed of a debris of greenstone elements. In the former case the resulting muscovadyte is siliceous and gneissic. but it always contains a large amount of biotite. In the latter the resultant rock is more highly biotitic, and frequently embraces hypersthene and olivine, plagioclase, magnetite, augite and diallage; and from this condition the transition is so easy to the gabbro that this phase of the older rock has been very generally assumed by former observers to be an accidental condition of the gabbro proper. Without a careful study of the field relations over very extended areas, the intermediate position of this softer mica schist, between gneiss and muscovadyte, and the transitions from the last into the gabbro, would hardly be recognized. This subject is more fully discussed later, in considering the gabbro of Lake county. A very favorable place for studying this series of transitions is along the Kawishiwi river in T. 63–9.

Along the southern shore of Disappointment lake this mica schist continues from the most southwesterly portion of the lake, but it shows in nearly all places a tendency toward the muscovadyte as seen at the iron locality S. W. ¼ N. E. ¼ sec. 4, T. 63–8 (No. 2197).

(4). Muscovadyte and iron ores. After what has already been stated, it is not necessary to dwell on the nature and origin of the muscovadyte and its contained ores. It is, of course, only an accident that the northern rim of the gabbro, with the accompanying alteration of the clastic greenstones, passes, along the southern side of Disappointment lake, so as to include one of the jaspilyte lenses of the Keewatin, in favorable position for studying its stratigraphy and its peculiar lithology. It was from this locality that was received the first correct conception of these ores. There are several similar local iron ore deposits, further toward the northeast, as well as toward the southwest, and they have been placed hypothetically in the base of the Animikie in all the annual reports, but it is now believed that they belong in the Keewatin, and were originally lenticular masses of jaspilyte identical to those which now exist in the Keewatin at Tower and Ely. Whether other iron ore deposits which occur well within the gabbro mass, and which are frequently titanic, can be assigned, any or all of them, to the same source, it is impossible to state; but it is reasonable to assume, under the view taken below of the origin of the gabbro, that they were likewise originally jaspilitic bodies in the Keewatin.

One of these deposits is in S. E. ¼ sec. 30, T. 62-10, at a distance of a mile and a half south of the margin of the gabbro. The ore is fine-grained and "olivinitic," similar to that north of Birch lake, and "the rock which contains it is a massive crystalline rock like gabbro, but stands in beds which are nearly vertical, though the dip is not constant. These strata are olivinitic, and, besides being finely granular, possess a banded structure. * * * The gabbro itself being also largely composed of magnetite here renders it more difficult to distinguish between the two kinds of rock." * The rock is here also quite hornblendic as well as quartzose. A quartzyte bed twenty feet thick runs along the northern side of this ore.

The iron which is on the north shore of Fraser lake, S. W. ¼ sec. 14, T. 64-7, is of the same kind. At the bottom of the shallow pits which have been sunk into it the ore is quite rich, though "olivinitic" (No. 248G). It is in bands running east and west, and dipping south about 80°, and is frequently quite quartzose, with evident bedding, and is associated with considerable deposits of coarsely crystalline hornblende; the country rock is frequently of the nature of muscovadyte. This iron ore deposit continues, apparently, into N. E. ¼ sec. 23, about a quarter of a mile further west, where it stands vertical, runs east and west and splits easily along parallel planes. It is here nicely interbanded with quartzyte, and the quartzyte becomes interbedded with a muscovado-like rock (No. 266G).

Another small exposure of similar ore occurs in connection with quartzyte and hornblende rock, N. E. ¼ sec. 29, north shore of Thomas lake.

THE IGNEOUS ROCKS OF THE KEEWATIN IN LAKE COUNTY.

(1). Granite and igneous gneiss. There are four areas of granite or igneous gneiss within the limits of the county, viz.: that of Bassimenan lake, that of White Iron lake, that of Snowbank lake and that of Kekequabic lake.

So far as known the first is intrusive only into the Lower Keewatin, and is supposed to be of the same age as the granite of White Iron lake, which also cuts the Lower Keewatin at Birch lake. The Saganaga lake granitic area is of the same age.

The granite of Snowbank lake is intrusive in the Upper Keewatin, and is probably of the same date as that of Kekequabic lake.

There are evidences also of two granites in the areas of White Iron lake and of Snowbank lake. There are dikes and bosses of fine-grained red granite, which cuts

* H. V. WINCHELL, in *Seventeenth Annual Report*, p. 96.

the older granite, and it is quite probable that, in the region southwestward from White Iron lake, where the Giant's range rises abruptly like a monster granitic dike, there is a later intrusion of granite which cuts an older (White Iron lake) granite, although there is no field evidence, other than the suddenness of the elevation of the Giant's range, of the existence of granites of two dates in the Giant's range proper. Two granites appear distinctly at several places about White Iron lake and on the Kawishiwi.

The Bassimenan (or Basswood) lake granite is well exposed on the islands and along the soath shores of Bassimenan lake. It is very often gneissic; *i. e.*, it is separated into sheets, generally from four to ten inches thick; which are either horizontal or show a dip toward the south, but sometimes as thin as half an inch to two inches. The partings are scarcely more micaceous than the rest of the rock, and it is evident that their distinctness depends much on the amount of atmospheric exposure which the rock has suffered. This granite is apt to vary to a syenyte, and occasionally hornblende crystals are coarse, *i. e.*, they are long and slender, as they fill vugs in the rock (No. 187W), or are blended in a compact hornblende mass. The rock also is frequently dark with the large content of hornblende. It is intrusive on the greenstones which it surrounds in small parts and converts to hornblende schists. Some phases of this rock are also dioritic. It sometimes is porphyritic with large feldspars. This area of granite has not been well studied.

At the Prairie portage, below the falls, sec. 2, T. 64–9, this granite appears as narrow dikes in the schists, and forms the first barrier of the outlet of Sucker lake. In its coarser aspects it is a characteristic hornblende granite, or syenyte, with quartz (No. 2211), but in many cases it is fine-grained, and, as the schist is granitized, the two are quite similar in some hand specimens (Nos. 2212, 2213). A view at Northeast cape, in Bassimenan lake, is shown by figure 2, plate AA.

The granite of White Iron lake extends into Lake county on the island formed by the branching of the Kawishiwi river. It is here (west side of T. 62–11) coarsely porphyritic with orthoclase (No. 136aE and Nos. 136bE, 953). This coarse composition prevails toward the northeast, the orthoclases being half an inch thick and sometimes reaching an inch and a half. A fine-grained syenyte is distributed through this rock, very capriciously occurring in dikes and veins, and sometimes in the form of larger masses or layers.

At the north end of Copeland's lake a change takes place. There is a dike running apparently north-northwest from the little bay in northeast corner of sec. 7, across the river, probably being the chief agent in determining the location of the rapids at the head of Copeland's lake. It cuts through syenyte. On the east side of this is much confusion in the character of the rock. Sometimes it is gneissic syenyte, not porphyritic. Sometimes it appears to be diabase in limited areas, and sometimes apparently a dioryte, and again a fine-grained syenyte, and a distinct gneiss, the last having a dip northwest about 80°. On the west shore, running from sec. 6 to sec. 5, T. 62–10, is a bold and conspicuous perpendicular wall of fine-grained syenyte, having a frequent jointage like an igneous rock. A little further east, near the town line between sec. 5, T. 62-10, and sec. 32, T. 63–10, on the west shore of the bay, the underlying rock is a peculiar greenstone or dioryte, firm

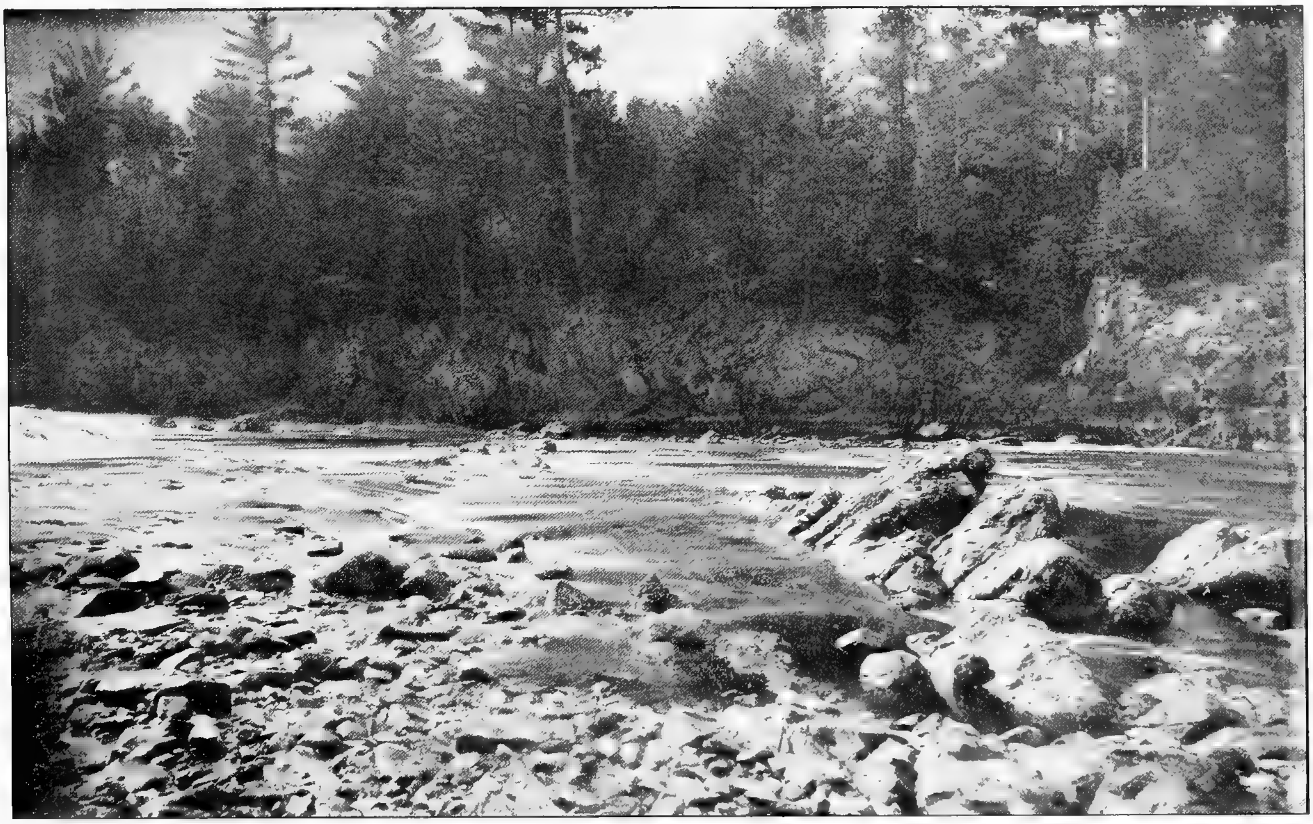


FIG. 1. QUARTZ VEIN IN GREENSTONE, CROSSING THE RIVER AT PIPESTONE RAPIDS, T. 64-11.

FIG. 2. NORTHEAST CAPE, BASSIMENAN LAKE. (p. 286.)

and tough, and very dark colored (rocks Nos. 2215–2220). This dark green rock is not a part of the Kawishiwin greenstone, at least in its present form, but is an igneous rock of later date. It becomes a coarse dioryte and then a syenyte, and passes by insensible gradations into the hornblendic and granitic rock of the country. It occupies a considerable area along the west side of the bay mentioned.

At the S. W. ¼ sec. 4, T. 62–10, is a nearly perpendicular wall of reddish, fine-grained syenyte, having the appearance of "palisades" and recalling the "great palisades" of the north shore of lake Superior. It stands in a rudely columnar and slightly sloping position, rises from the lake level to the hight of forty or fifty feet and extends along the lake shore about twenty-five rods. Long columns fall away. The same red, fine-grained syenyte appears in the bay in sec. 9, T. 62–10, and along the bay into which the river flows from the southwest. This red syenyte (No. 979), which sometimes is very hornblendic, continues to the gabbro contact, S. W. ¼ sec. 9, T. 62–10, where it is embraced more or less within the gabbro, apparently as inclusions.

Similar fine-grained red rock appears on the west side of White Iron lake, N. E. ¼ N. E. ¼ sec. 14, T. 62–12, forming a ridge at the lake, forty feet high, sloping to the north and west (No. 24E). This has a fiery red color, and is about twenty feet thick, massive and dike-like, stands nearly vertical, with a sharp contact on the granite. Veins of red rock run from the main mass into the surrounding granite, showing the later origin of the red rock.

At numerous places along the Kawishiwi the same rock appears. Near the centre of sec. 26, T. 63–10, on the north side of the lake, the outcropping syenyte is very hornblendic, making nearly a black rock. In patches, however, is seen a fine, red syenyte, the transition from one to the other being abrupt. The red syenyte becomes at once the prevailing rock, and is much developed in hills about fifty feet high, in N. W. ¼ N. W. ¼ sec. 26, T. 63–10.

On the N. W. ¼ sec. 27, T. 63–10, is a fine-grained, firm, slightly micaceous quartzose (and also feldspathic) gray rock (No. 989) with evident sedimentary bedding E. 50° S., at an angle of 75° from the horizon, resembling a graywacke in color and grain. The few "mica" scales seen are not of biotite, but are greenish. It is similar to some graywackes seen at Vermilion lake. Across the river north-northeast from this rock is a nearly white gneissic rock, a kind of feldspathic graywacke, dipping northeast. This has some reddish weathered spots. In the line of strike east from No. 989 is a small island in the lake, so near the shore that it cannot be of any other rock than No. 989. It contains rock No. 991, and, while it is gray within, and has the same gneissic or faintly bedded structure, it weathers light red, and at a short distance it might be taken for fine red syenyte.

A little east of No. 990 appears No. 992, a kind of chloritic syenyte. This is massive or heavily bedded, without gneissic structure, weathers red—apparently an irruptive rock, at least being outwardly disposed like an igneous rock. It is closely cross-jointed, making small lenticular angular blocks. It continues east along the north shore (No. 993) as far as the quarter-post of section 22, and becomes the red syenyte noted further east.

On the point between the two bays on the south side N. W. ¼ sec. 27, T. 63–10, the rock is the same as rock No. 991 and dips southerly, but with a less evident gneissic structure. Finely twisted and back-folded bedding can be seen on the weathered surface, like some seen in the graywacke on sec. 20, T. 62–15, showing a former plastic or nearly plastic condition. In the midst of it appears rock represented by No. 994, which is a fine red quartzose rock. This is taken at random from the surface of this graywacken gneiss. It is sub-crystalline, yet contains many fragmental grains. The color is light red, sprinkled through, or about evenly divided, with a light green, the former being apparently orthoclastic and the latter epidotic. "This shows the possibility, nay the actuality, of this graywacken gneiss becoming the prevailing red syenyte of the region, the whole having resulted, as already intimated, from a modification of the sedimentaries. This graywacken gneiss, when fused completely, seems to have produced the rock No. 993. When changed less it constitutes the 'palisade rock' of the region, and mingles with the gabbro. When less changed it makes the red-weathering, fine, sub-crystalline gneiss. This interesting observation, while it may not account for all the red syenyte and gneiss of the region, yet affords a plausible supposition for the origin of that which is associated closely with the gabbro rock."*

Another form of the modified sedimentary rock is No. 995, which succeeds to the rock No. 991 in N. W. ¼ sec. 28, T. 63–10. It is hornblendic, quartzose, orthoclastic—at least has reddish feldspar grains (not crystals)—gray and firm. It is micaceous in streaks or laminæ. It makes the long rapids here, and rises in the form of a ridge running northeast and southwest, in the direction of the strike of rock No. 991, rising about eighty feet above the river. The general structure dips southeasterly at an angle of 80° from the horizon. Along the immediate river channel this rock rises on the right and left somewhat in the manner of the fine red syenyte or "palisade" rock, nearly perpendicular, having a jointed and pseudo-basaltic appearance. It is apparently irruptive in the greenstones of the Lower Keewatin, as well as in the coarse porphyritic granite of the White Iron Lake region.

The granite and porphyry of Snowbank lake. The lake itself occupies the most of the area of this granite, but about the shores it is frequently seen penetrating the conglomerate and the mica schists of the Upper Keewatin. It extends nearly across the narrow strip of land separating Snowbank lake from Disappointment lake. It has been noted that in places this granite is augitic (Nos. 522G, 524G, 271E

* *Fifteenth Annual Report*, p. 353, 1886.

and 2194), resembling in that respect that of the region of Kekequabic lake. It is not believed that this is due to any difference of origin or of date, but that the augitic character appears sporadically according to the nature of the clastics from the metamorphism and fusion of which the granite is supposed to have been derived. Very frequently this granite is rather a syenyte or occasionally a dioryte (No. 487G).

One of the most interesting features of the granite of Snowbank lake is its relation to a porphyry, sometimes a quartz porphyry, and sometimes a granite porphyry (Nos. 1729, 2189, 2196, 270E, 290G and 497G), and through this rock to the porphyritic conglomerate of the region which is a part of the Upper Keewatin.

There is a noticeable parallel between the geology of this lake and that of Kekequabic lake. In each there is a porphyritic conglomerate, a porphyry which becomes granitic, and a granite which is sometimes augitic. At Kekequabic lake the porphyry is known also to be sometimes augitic, but that character has not yet been observed certainly in the porphyry of Snowbank lake. Field observations by nearly all members of the survey testify that the conglomerate is so nearly related to the porphyry that they cannot be separated in many instances. This is a repetition of the fact which has been observed in other places, notably about Zeta lake, where a porphyritic conglomerate acquires the outward characters of an intrusive, and even at Vermilion lake, where by pressure some of the coarse fragmentals have been crowded into the spaces separating broken parts of the surrounding clastics. The conglomerate being thickly sprinkled with fragments of feldspar crystals, which are sometimes accompanied by quartz, and also by fragments of granite and of jaspilyte, must have been originally of fragmental origin and mechanical accumulation. The "porphyritic" appearance is due therefore to the nature of the debris, and not to a formation of feldspars afterwards. These feldspars are not always found, but the rock grades into graywacke and to argillyte. By the metamorphism which was imposed on this fragmental rock, and which was accompanied by pressure and folding, and resulted, in the granitic area, in the complete fusion of the clastic materials, a great variety of structural as well as petrographic facts of importance and high geologic interest were developed. The petrology of the rocks collected about Snowbank lake has not been so completely investigated as that of the rocks of Kekequabic lake, but as the two regions are unquestionably parallel in their leading features the conclusions derived from one may be applied to the other. The important facts are:

1. Transition from the conglomerate to the *porphyrel* and to porphyry.
2. Transition from the porphyry to the granite.
3. The granite cuts the conglomerate, and also the porphyry.
4. The formation in general, when it was not fused, is re-crystallized, and its conglomeratic composition is still apparent in the mica schist which resulted.

5. The mica schist is sub-granitized over large areas, weathering red like a fine-grained granite, though still retaining its sedimentary banding.

6. The coarser beds of the formation, especially the conglomeratic, are first to show the effects of re-crystallization, and apparently first take up the rôle of an intrusive.

7. In the process of re-crystallization of a conglomerate containing clastic feldspars, the fine matrix is completely micro-granitized and interlocked, the original outlines of the fine grains being lost, thus forming a ground mass, as of an igneous rock. As the grains are larger and larger, they show more and more distinctly their original forms, but this depends also on the intensity of the metamorphosing force, which obviously varied from place to place. As the feldspar fragments become coarse enough, at any point in the sedimentation, to preserve their outlines after metamorphism, they are seen to be interlocked about their margins, by the addition of zones of new feldspathic growth, into the fine surrounding matrix, and also to contain new feldspathic restorations. Such new growth is sometimes in the form of microperthite, following the original lamination or cleavage of the feldspars, but is more frequently distributed irregularly throughout the original grains.

8. A granite results from this process by increasing either the intensity of the metamorphism, carrying it to aqueo-igneous fusion, or by beginning with a clastic of uniform granular composition. In the former case the coarser, if not the coarsest, of the original grains lose their outlines, and in the latter, by any degree of metamorphism, a granitic texture is acquired. But in both cases the original clastic grains can still be detected, in numerous thin sections, by the differences existing between the old feldspars and the restorations, and in the latter case there might be a complete petrographic gradation from granite, through a fragmental gneiss to graywacke and to any ordinary grit.

9. Quartz serves as the readiest element to suffer these changes and to act as a new cement, taking the forms of micro-granulyte and micro-pegmatyte.

10. The ferro magnesian elements of the original clastic, when they exist, are changed, for the most part, to hornblende, but in the porphyry and granites of Snowbank and Kekequabic lakes it sometimes retains its augitic characters, in whole or in part.

11. It is evident that the more fluid parts of the altered rock would necessarily penetrate openings in all the less fluid, and for that reason the granite forms intrusions on the porphyry and on the schists; yet this is not invariably the case, for at contacts of the granite and the porphyry the latter has been seen entering the former as little finger-like dikes over small distances, as though the porphyry were in a fluid state later than the granite. Such variations might take place by reason of a temporary release or shifting of the centre of metamorphic intensity.

12. From the nature of the case the intrusive porphyry exists in limited amounts, while the granite occurs in large bosses and as wider dikes. A fusion on a sufficiently large scale to form a large amount of intrusive porphyry would require so slow cooling as to convert the fused rock necessarily into a granite.

13. The belt of metamorphism and fusion of the Upper Keewatin clastics witnessed at Kekequabic and Snowbank lakes was perhaps cotemporary with the formation of the fine red granites which appear on the Kawishiwi and on White Iron lake, cutting the White Iron Lake granite, and perhaps the dikes occasionally seen in the Lower Keewatin graywackes and schists between White Iron lake and Snowbank lake. Whether this epoch of folding and metamorphism was also that which gave origin to the gabbro which is immediately adjacent on the south is not now known, but, while it is reasonable to suppose it was, there are differences which indicate that the gabbro was later. In any case, the molten rock, which becomes the intrusive, was caused to set back, sometimes several miles, upon the strata still unfused, and to penetrate and even overwhelm them in a general catastrophe. Usually such intrusives only penetrate the strata from which they are derived or those of later date, but occasionally they penetrate older rocks which lie within the course of the metamorphic belt. Thus occur a few acid dikes in the oldest greenstones southward from the Saganaga Lake granite boss, and perhaps others in the Kawishiwi valley, T. 63–10.

There is a porphyry which belongs in the Lower Keewatin which should not be confounded with this porphyry-conglomerate. That, probably, was in part the source of the fragmental feldspar crystals seen in this, when they were not derived from volcanic action in Upper Keewatin time. The older porphyry is more distinctly an igneous rock, and is described in a subsequent paragraph.

The remarkable conglomerate which forms the basal member of the Upper Keewatin exhibits a composition dependent on the nature of the rock from which it was derived. Its so-called porphyritic aspect, forming "porphyrel," is predominantly displayed between Moose and Snowbank lakes, but it also extends southwestwardly into T. 63–9, and northeastwardly to Kekequabic and Ogishke Muncie lakes. Its double rôle of sedimentary and intrusive is abundantly evinced by the statements of the field-books of A. Winchell, A. H. Elftman, H. V. Winchell, U. S. Grant and of the writer, although, in some instances, without a full apprehension of the significance of the anomalous facts recorded. Therefore, there has been a varied interpretation. By A. Winchell the facts were fully understood at the localities examined by him. By Mr. Elftman the whole conglomeratic belt between Snowbank and Moose lakes was considered of igneous character—a porphyry mass of the Lower Keewatin cutting the greenstone—the source of many of the pebbles seen in the western portion where the conglomeratic composition is well preserved. Still, he makes record of the fact that, as a porphyry, it contains boulders and also cuts the Upper Keewatin. H. V. Winchell states that the porphyry becomes conglomeratic, and Dr. Grant reports the anomalous fact of a conglomeratic granite at Kekequabic lake, which he cannot explain, and leaves it in doubt whether it constitutes a part of the granite of the region.* The actually intrusive action of this conglomerate, where it contains conspicuous feldspars, is visible only in the region west of Snowbank lake and round the borders of the small granitic boss at Kekequabic lake. Where it does not contain conspicuous feldspars, and acts still as an intrusive, the rock is a fine-grained granite without noticeable peculiarities, for, where the coarse feldspars are wanting in the original, it is evident that no pebbles of any kind large enough to warrant the term conglomerate could have been gathered under the action of sedimentary selection, and the granitizing of such a rock without complete fusion would produce a non-porphyritic granite.

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*Chapter xxiii, Fraser Lake plate.

It has been noticed, also, that the finer portions of the original clastic formation sometimes survive *en masse* and maintain their outward characters longer than the coarser, and thus make their appearance as bands and as fragments in the midst of the coarser materials after the granitization of the formation.

There are several dikes of porphyry in the region of the Kawishiwi, T. 63–10, which are supposed to cut the Lower Keewatin (Nos. 300G, 402G, 403G, 411G, 413G–415G, 417G, 458G). This rock is quite similar to the porphyry which cuts the Upper Keewatin west of Snowbank lake, when examined microscopically, and also is like the porphyry which occurs at Kekequabic lake. If these dikes preceded the Upper Keewatin, thus being probably cotemporary with the origination of the White Iron Lake granite, they may have united with that granite (which is often conspicuously and coarsely porphyritic) in giving clastic feldspars to the conglomerate of the Upper Keewatin. Their source, therefore, under the hypothesis of this chapter as to the origin of such intrusives, must have been from some acid materials of the Lower Keewatin, and perhaps from an acid fragmental not yet identified in the Lower Keewatin. But these dikes may also be of date later than the Upper Keewatin, whatever their source, for they are in the metamorphic zone which crosses the county from White Iron lake to Kekequabic lake. In that case they may also have originated from a possible acid fragmental in the Lower Keewatin, as above, or they may be the result of a sidewise intrusion of fused or plastic Upper Keewatin into the Lower Keewatin at the date of the origination of the granite of the region of Snowbank lake. Mr. Elftman has also noted such dikes cutting the greenstones south of Moose lake.

Numerous details of field-observation will be found in the chapter (XXII) devoted to the Snowbank Lake plate.

Note. Later observations made in September, 1898, in the region southwest from Snowbank lake, afford some interesting facts respecting the Lower Keewatin porphyry above mentioned.

At the east side of sec. 8, T. 63–9, near the quarter post, is a large area of this rock (No. 2228), extending westward. Its orthoclase crystals are rather fragmentary, yet one crystal was seen an inch and a quarter in larger diameter. Two diabase dikes here cut this rock, one being four feet wide and the other an inch and a quarter. This diabase sometimes shows clusters of crystals of plagioclase. The porphyry holds rounded quartz pebbles, sparsely as a usual thing, and rather fine, resembling porphyritic quartzes, but one was seen which measured three-fourths of an inch in diameter. It also contains occasionally pieces of greenstone. It is seamed with veins of finely granular quartz of the jaspilitic sort, and of vitreous quartz, the latter in large deposits.

The contact of this porphyry is on a greenstone conglomerate, which conglomerate lies on the agglomeratic Lower Keewatin greenstone, and contains only greenstone materials. The porphyry is mainly green at the point of contact, but is spotted with rounded fragments of white and red jaspilitic silica. Although in one place these two rocks were seen to approach each other within two or three feet, it was not possible to find them in absolute contact. Near the plane of contact, at a short distance either way from the place at which the two rocks were seen near together, are large deposits of vein quartz which belong in the porphyry.

There is no appearance of any porphyry ingredients (orthoclase crystals and vitreous quartz) in the greenstone conglomerate, but there are a few fragments of greenstone in the porphyry. The whole structure is elongated N. 65° W., as shown by the shapes of the green pebbles in the greenstone conglomerate.

There is a swampy tract near the same quarter post, now nearly free from vegetation by reason of a burning four or five years ago, in which the surface is composed of boulders, ninety-nine per cent. of them being apparently of this porphyry. One of these boulders seems to have come from the plane of contact between the greenstone conglomerate, above mentioned, and this porphyry. There seems to be here a transition from the greenstone conglomerate to the porphyry, as shown by the figure below.

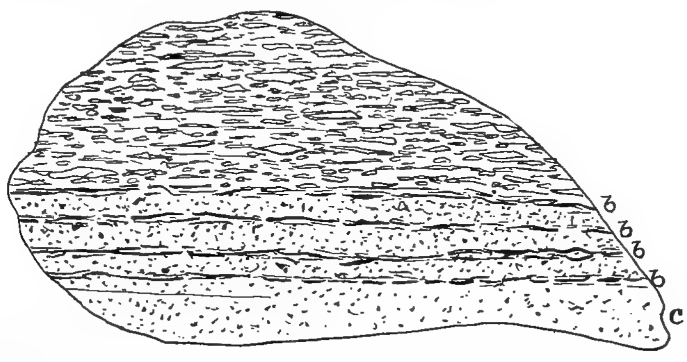


FIG. 38. ALTERNATING MANNER OF CONTACT OF PORPHYRY ON GREENSTONE CONGLOMERATE.

There are three bands of porphyry about three-quarters inch thick, separated by three bands of green schist, about one-eighth inch thick, the whole transition being complete in about four inches. This has the characters of a sedimentary transition. The materials of the porphyry are rather fine at first, but constitute a real porphyry which is otherwise like the body of that rock, except being a little darker colored, perhaps by reason of disseminated green element from the greenstone.

Following the strike about northwest, at a distance of about one-quarter mile from the section line, and further, along a spur of high land, the north-south order of occurrence of the various rock masses is found by

the observer to be as represented by the following diagram, figure 39, which may be supposed to include the interval of about a mile and a half, the larger part of that interval being occupied by a greenstone which is frequently agglomeratic, and extending north from the great greenstone ridge which is a conspicuous landmark existing at the corners of secs. 8, 9, 16 and 17, T. 63-9. Immediately to the north from this ridge is a thin band of greenstone conglomerate which, at the point examined, has a thickness of 105 feet, the structure standing vertical and striking northwest. The manner of transition from this conglomerate to the porphyry has not been seen *in situ* but is supposed to be represented by the boulder sketched above (figure 38). It would be unwarranted to base an important conclusion on a single observation, especially as the boulder examined may have had some other source. Yet, as no instance was found of the intrusion of this porphyry into the greenstone to the south of it, there is no authority aside from the nature of the rock to assume an igneous contact on the greenstone conglomerate. The porphyry, however (No. 2229), furnishes much debris to the conglomerate (No. 2230), which overlies it apparently by regular detrital sequence. This porphyry conglomerate can be seen here only six or eight feet thick. It fades out soon into a greenstone (No. 2231) which appears to be massive, but which is to be classed provisionally with the fragmental greenstones of the Lower Keewatin. This later fragmental greenstone is therefore separated from the more clearly igneous (and earliest) greenstone by a remarkable band of porphyry. It develops further north into an extensive formation having an indefinite thickness, and as a conglomerate it extends westward as described below.

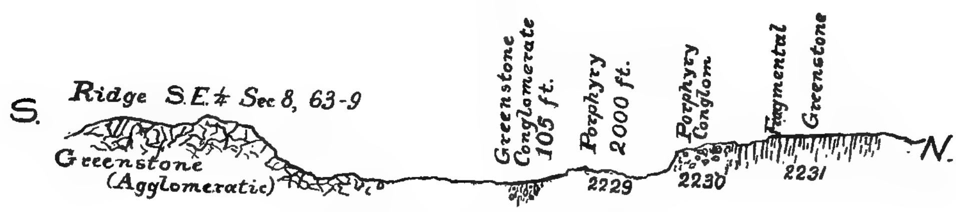


FIG. 39. NORTH AND SOUTH SECTION.
East side of sec. 8, T. 63-9.

The greenstone conglomerate contains, so far as can be seen, nothing but greenstone debris, and fine jaspilitic silica in small pebbles. The largest pebbles are from two to three inches in their longer diameter, but in general they are about half an inch. The conglomeratic character fades out into a green schist, with a vertical structure in both.

In the porphyry there are sometimes indistinct traces of a banding like sedimentation, but, in general, this rock is homogeneous, massive, hard and jointed like an igneous rock. It is not always porphyritic, but has a graywacken aspect. Indeed, there is more of the non-porphyritic than of the distinctly porphyritic, but there is no possibility of separating one from the other. So far as can be seen here this poryhyry can be considered one of a successional series of strata laid down by oceanic forces, and such it would be considered in the light of all that can be discovered, were it not for the nature of the rock, which, according to universal acceptance, requires that it be classed as an igneous intrusive. (Compare the twenty-fourth annual report, p. 71.)

To the north of this porphyry, as already mentioned, is a belt of supposed fragmental greenstone. This belt, on the section line between secs. 8 and 9, T. 63-9, is about 275 feet wide, and next north of it appears a rock similar to the porphyry, but a little finer grained and somewhat schistose, with a coarse, rough structure. Again, north of the quarter post, which is at the creek, the porphyry reappears, somewhat schistose and rough, approaching graywacke. At still further north, perhaps a quarter of a mile north of the quarter post, the porphyry varies to a gray, siliceous, hardly porphyritic rock (No. 2232), a near approach to graywacke. This continues northward for quite a distance, when a green phase comes on (like No. 2231). This rapidly fades out into a bluish-green, coarse, schistose slate, then to a lighter coarse slate or graywacke, which continues north to the swamp. In the swamp, at fifty paces south from the section corner (northwest corner section 9), are low, moss-covered knobs of slate (No. 2233), which is apparently cut by a dike of greenstone running northwest (No. 2234). No idea of the structural relations of the parts noted in this section lying northward from that shown in figure 39 could be obtained in the rapid traverse made. The rock simply varies from point to point, as noted.

This porphyry is seen again extensively in making a trip along the north side of section 8 in the same town. Starting from the northeast corner of the section, after a swamp of a quarter of a mile, rocky country of low hills supervenes, from which the forest has been burnt. At first these hills consist of graywacke, rather coarsely schistose and hardly showing any sedimentary banding, but striking N. 25° W. (magnetic). Here is also a greenstone later than the porphyry, for it contains mass of the porphyry. These two rocks occur here in isolated knobs and short ridges, quite irregularly and regardless of the northwest strike. This greenstone (Nos. 2235, 2240) also carries fine pebbles from the porphyry, strung out northwest in a sedimentary manner, the pebbles being from one-eighth to three-fourths of an inch in diameter. It is plain, from the structures seen here, that there is great confusion, consequent, probably, on the abnormal strike; and it is to be presumed that the generally mixed arrangement of the two rocks is due to that greater irregularity. The greenstone here shows no agglomeratic structure, but it is hard, massive, jointed irregularly and seamed, and at the southern border is crowded with porphyry debris (plate Z, figures 1 and 2).

At 650 paces west of the corner post is a north and south greenstone dike (No. 2236) cutting the quartz porphyry. About four rods west of this dike* is an evidently fragmental spot in the porphyry. The whole rock is roughly schistose in a direction about E. 25° N., ridged with interrupted finer belts resembling siliceous argillyte, and holds pieces of greenstone and slaty greenstone varying in size from ten inches (rounded) to one-half inch. It also has pieces of jaspilyte and rounded quartz. The slaty greenstone is like argillyte, and runs usually with the structure, standing on edge. It (the porphyry) contains much quartz in grains less than a pea, but also as large as an inch in diameter, the last being very rare. At the same time quartz grains that cannot outwardly be distinguished from the quartzes of quartz porphyry are abundantly disseminated through the rock. Indeed, the bulk of the whole consists of more or less rounded fragments of orthoclase and quartz, lying in a fine pellucid matrix, which also appears to be essentially quartz, in sufficient abundance to keep the coarser grains from interlocking, but allowing them to come loosely into contact (No. 2237).

There are variations in this porphyry. Sometimes it has much and distinct orthoclase, and in other cases none. It also varies to an exceedingly fine-grained rock with no apparent quartz nor feldspar, as crystals; but yet on close examination it is seen that fine quartz grains are still present. In other cases it holds vitreous quartz grains surrounded by a mesh of quartz which is apparently like that of the jaspilyte, *i.e.*, very finely granular (No. 2238). Indeed the rock shows some alliance in structure and composition with the well known jaspilyte.

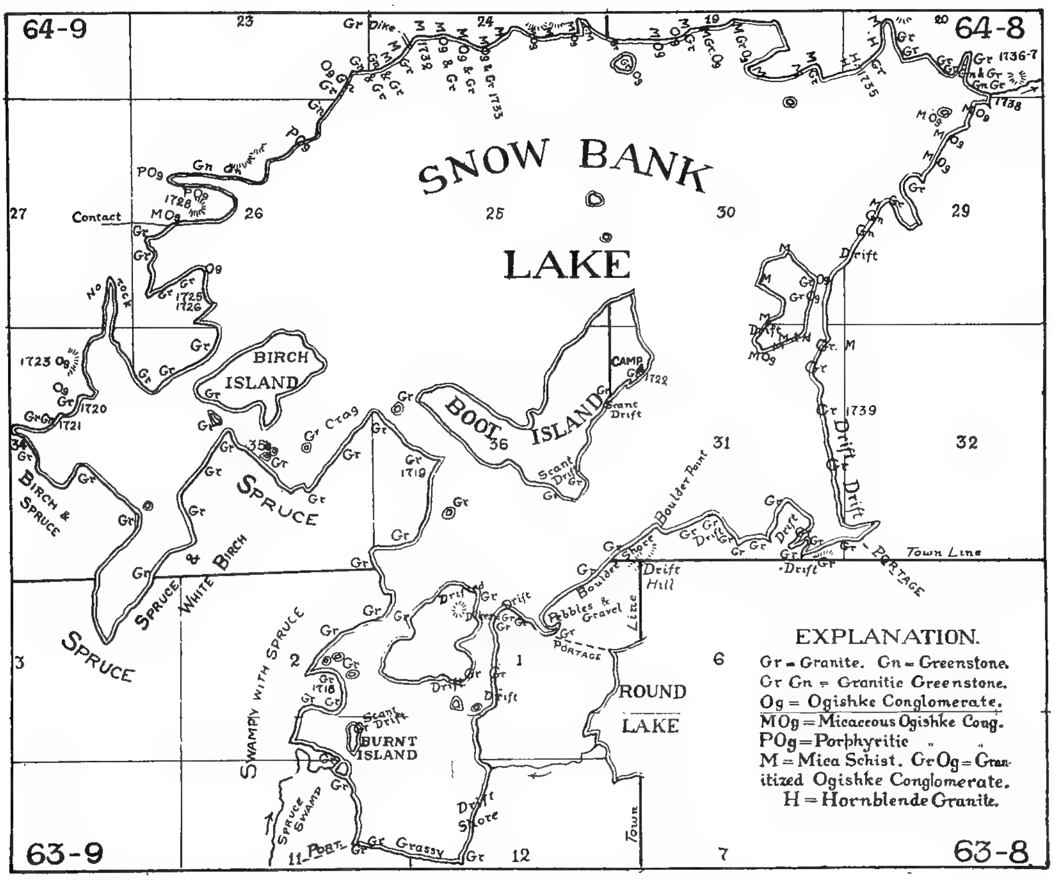


FIG. 40. THE GEOLOGY OF SNOWBANK LAKE.

Outcrops occurring in the swamp, just west of this dike, show a sub-granitic rock (No. 2239) resembling the grayish-red granitic rocks at Kekequabic lake, but on the westerly side of this swamp the porphyry has abrupt contacts on a greenstone containing original jaspilyte. Such contacts could be formed by the folding and twisting which the rocks have suffered here. The porphyry occurs suddenly in knobs and small areas, sometimes coincident with the schistosity of the greenstone and sometimes across it. The region is plainly one of great dynamic displacement, and such relations may be due entirely to such displacement. The conglomeratic transition (No. 2240) from the porphyry to the fragmental greenstone occupies normally about four feet; but large masses of the porphyry, apparently detrital, are in the greenstone at greater distances, say fifty feet, from the porphyry, while at the same time larger masses are detached, evidently by folding, these being some-

* This dike is that mentioned by H. V. Winchell, and described as passing under Copeland's cabin (No. 516H). *Seventeenth Annual Report*, p. 123.

times very large and sometimes consisting of parts of this conglomeratic zone. Such features are visible N. W. ¼ N. E. ¼ sec. 8, T. 63-9, at 430 paces west and about eighty paces south of the northeast corner of section 8 (see plate Z, figures 1 and 2).

There is here visible also a conglomeratic phase which comes on toward the northeast from the mass of the porphyry appearing like the Upper Keewatin. It embraces quartz porphyry pebbles, with quite a number of greenstone, of hard, flinty slate, jaspilitic quartz and gray quartzyte. This change is within a foot, and the apparent base for the conglomerate is the porphyry itself. The conglomerate has a thickness of about twenty feet and grades off to a graywacke which is distinctly bedded. The pebbles of the conglomerate are small, and the rock so gradually passes in the other direction into the non-conglomeratic kind that it is impossible to point out the contact with the porphyry proper. It is evident that throughout this region of porphyry there are massive areas of porphyry, sometimes sub-granitic, and other areas of detrital rock largely derived from such porphyry, which can hardly be distinguished, at least in the field, from each other.

It will require much time and more careful study than it has been possible to give to this rock in this region to warrant any attempt to outline it geographically, or to distinguish the massive from the fragmental. Added to the great resemblance of the fragmental to the massive, is the broken and folded condition of all the formations, which increases the intricacy of the structure and the difficulty of the tracing out of the different parts.

Between Moose and Flash lakes, T. 64-9, and occupying a tract of high land running northeast and southwest for several miles, may be seen much of the porphyry above noted. It is closely folded with beds that have been formed by debris, from it and from the Keewatin greenstones, involving the stratigraphic line of separation of the Upper Keewatin from the Lower. There is a succession of ridges of greenstone and porphyry, the most southeastern hill range being of agglomeratic greenstone, and the rocks toward the northwest being in the higher stratigraphic horizon. The most characteristic features of the Stuntz conglomerate are near Moose lake. The strata stand sometimes vertical, but sometimes dip at a high angle toward the south or southeast.

The outline sketch of Snowbank lake on previous page (figure 40) shows the geology of its shores as made in the field by the writer in 1892.

The granite of Kekequabic lake. The characters, both microscopical and regional, of this granite, are given in detail by Dr. Grant, in the chapter (xxiii) devoted to the Fraser Lake plate. A large series of thin sections from this locality have been examined, and the results of petrographic study are given in the chapter devoted to that subject. These results are also summarized in the chapter on Structural Geology in vol. v. They are practically the same as those already stated for the Snowbank Lake area. Dr. Grant's description goes into the details of the mineralogy of the granite and the porphyry, and recognizes fully the wholly crystalline and plainly intrusive features. It may be well to direct attention to the rocks which are not fully described in that chapter, but which are designated "contact rocks," and "hornblendic phase of the granite," the latter being plainly conglomeratic, for in these apparently exist the links that bind the fragmental rocks of the region genetically with the intrusive.

(3). Later dikes of diabase. Throughout the county, north of the northern border of the gabbro, are found dikes of fresh diabase. They are the latest formed rocks of the area of the Keewatin, but belong to the date of the Keweenawan. These dikes are usually over six inches in width, and not infrequently they are from ten to fifty feet. They run in all directions, and are frequent near the northern border of the gabbro, from which they are presumably peripheral offshoots.

There is another series of diabasic rocks, not generally occurring as dikes, which apparently have a different origin and an earlier date, to which brief allusion should be made. They are constituent parts of the Lower Keewatin, and to some extent also of the Upper Keewatin. They lie in the axis of the metamorphic belt

but outside of the areas where that metamorphism resulted in the fusion of the acid clastics, and seem to be due to the same metamorphism exerted on the greenstones. They have been mentioned in Ts. 63–9 and 63–10, where they embrace sometimes the jaspilyte ores, but they also occur in the general greenstone areas in other towns, and in some cases they are closely associated with the Upper Keewatin about Snowbank lake. They have not been differentiated carefully from the intrusive diabases, nor have they been studied petrographically. It is simply suggested here that they are metamorphic conditions of the greenstones of the Keewatin, sometimes of the massive and sometimes of the clastic portions. If the greenstones received the pressure and heat which converted the conglomerates, etc., into granite, they were probably reformed, and may not only have been converted into fresh crystalline diabases, but may have penetrated the adjoining rocks as dikes in the same manner as the granite. This may be the source of some of the diabase dikes that occur in the northern part of the county. If the greenstone formation be allowed to be the primordial crust of the earth it must underlie all the granitic and other rocks, and in case of folding and fissuring of the overlying rocks this basement of greenstone would be likely to send numerous tongues upward through the granites at great distances from any surface exposure of the greenstones, and this may have occurred at any of the epochs of folding and fusion.

THE TACONIC.

The rocks which succeeded to the Keewatin in Minnesota are divisible into Animikie and Keweenawan, and are believed to be of the age of the Lower Cambrian, which in America early received the name Taconic. These parts are separated by a non-conformity which, though not conspicuously exhibited in Lake county, is marked by a basal conglomerate and a quartzyte. It is an interesting fact that these parts are both profoundly affected by igneous basic rocks. The earlier part, however (Animikie), is not known in Minnesota to have been accompanied with cotemporary surface eruptions. Its igneous rocks are all (or nearly all) of later date than the clastic rocks of the formation itself, and take the shapes of dikes, sills (*Logan sills*, so named by Lawson), and perhaps small laccoliths, of the date of the gabbro or of some later intrusives. The Keweenawan, however, beginning, chronologically, with the basal conglomerate lying on the Animikie, and its eruptives, was accompanied by cotemporary surface lavas, often of great volume, which formed sheets that spread connectedly over many miles of surface, and which are separated, toward the end of the formation, by beds of red sandstone, or by sandstone and shale. As the igneous activities waned the region gradually sank, allowing the ocean to cover large areas which had been dry land, and the later deposited fragmental rocks are much thicker and more extended than the earlier. On the entire

cessation of igneous activity the sandstones, becoming white and siliceous, increased still in thickness, and finally were replaced by magnesian and argillaceous limestones, which are conformably interstratified with them, thus introducing the Hinckley and St. Croix series, the equivalent of the Upper Cambrian.

When the term Keweenawan is applied to the rocks of Minnesota a certain degree of confusion is introduced, since it was made to cover the igneous rocks of the Animikie and of the sandstones and conglomerates which lie above the Animikie. The igneous intrusions into the Animikie (the gabbro and the red rock) and their surface equivalents, were completed before the date of the great conglomerate, and chronologically have therefore nothing to do with the Keweenawan. As an appellation for the igneous rocks simply, regardless of the chronologic extent of the term Animikie, Keweenawan has significance, but as a time division, beginning after the Animikie, it should exclude a large part (probably the greater part) of the basic igneous rocks to which it was applied, so far as they occur in Minnesota. The base of the conglomerate is a chronologic datum which should separate the formations.

The Animikie. There is not a known exposure of unquestioned normal Animikie in Lake county. There is a conspicuous belt of "red rock" which is supposed to have resulted from the fusion of the Animikie (and perhaps older rocks), crossing the county from southwest to northeast, south of the main gabbro belt, but this will be treated in the discussion of the igneous rocks of the Taconic.

There is also a series of outcrops of iron ore which in the annual reports and in the bulletins have been referred to the Animikie. They are the quartzose and olivinitic ores that occur near the northern border of the gabbro, associated in all cases with a greater or less amount of muscovadyte, which are now referred to the Keewatin, having received their present characters by the action of the gabbro revolution upon the jaspilytes and associated greenstones of that formation. These ores have already been described under the heading *Muscovadyte and its iron ores,* in a previous part of this chapter.

The strike of the Animikie strata is approximately represented by the band of red rock, and as this runs along south of the main gabbro mass, and has a general agreement with the major structures of the northeastern part of the state, it appears to be, primarily, located by those orogenic forces which determined the position and form of the northwestern environs of the lake Superior basin, and in that respect the red rock, as well as the gabbro, shows an alliance with those great land movements which have always determined the limits of the oceanic formations. These rocks now have a distinctly igneous nature, but their distribution and position conform to a possible earlier clastic nature, when they were brought to the general positions they now occupy. In the absence of definite facts bearing on this question

within Lake county, it can only be assumed here as a plausible hypothesis that the red rock represents the original Animikie, after fusion and more or less transportation from its original strike. (Compare chapter xxviii, Pigeon point.)

The gabbro and other igneous rocks of the Animikie. Facts which are detailed in the chapters devoted to the region of Pigeon point and that of Duluth (plates lxxxv and lxxxviii) show the necessity of dividing the Keweenawan igneous rocks of Irving into two parts, the earlier having penetrated the Animikie and fused it and become consolidated prior to the accumulation of the next fragmental, the great Puckwunge conglomerate, and the later occurring as surface flows after the formation of the conglomerate, and to some extent during the conglomerate. This separation into upper and lower, or later and earlier, is quite different from all the divisions introduced by Irving. His "Upper Keweenawan" included the later diabases and much of the red sandstones—*i. e.*, the "tilted red sandstones"—and the lower diabases with the gabbro were included by him in the "Lower Keweenawan." In order that the upper and lower Keweenawan, as described in this report, may not be confounded with the designations employed by Irving and the Wisconsin reports, it has been thought best to apply new names to the two parts, viz.:

Cabotian, including the gabbro, anorthosyte, red rock and the great Beaver Bay diabase, with all surface lavas that preceded the Puckwunge conglomerate. This name is taken from the ancient name applied by Buchette, according to Schoolcraft, to the mountain range that appears at Duluth formed by the gabbro, and which extends in general eastward, outlining the rim of the lake Superior basin, throughout Minnesota.

Manitou, including the igneous rocks from the Puckwunge conglomerate to the top of the igneous series. This upper limit will not appear at the same stratigraphic horizon at all points, because of the probably longer duration of igneous activity at points further east than at the western extremity of the lake Superior basin. This term is taken from the Manitou river which enters lake Superior in this county, where are exposed some of the lower traps of this division and some of the upper portions of the conglomeratic beds, although not the Puckwunge conglomerate.

In Lake county the gabbro, at its widest place, covers twenty-five miles, and at its narrowest twenty-one miles, and its length is forty-two miles. Its superficies is hence about 575 square miles within the county. Along its northern border it comes abruptly into contact with the White Iron Lake granite and with different parts of the Keewatin. Its southern limit is in general the northern limit of the red rock, but there are numerous places where these rocks are intricately inter-locked, and in some instances isolated areas of the red rock are surrounded by gabbro. Generally

such isolated areas of red rock have been omitted in the mapping seen on the accompanying plate.

Date of the gabbro. It is not certain, nor indeed is it probable, that the gabbro revolution followed immediately after the completion of the fragmental beds of the Animikie. The absolute summit of the Animike is an elusive geological datum, not yet certainly determined. Some observations recorded in the Pigeon Point chapter (xxviii) tend to show that the Animikie was followed by a gentle igneous epoch, accompanied by surface lavas and probably by volcanic ash, before the great convulsion which introduced the sills and dikes, and this is in agreement with the record of the deep well sunk at Short Line Park, near Duluth, and also is indicated by the superposition of the Beaver Bay diabase upon some diabases and soft conglomerates—that diabase being supposed to be the great surface representative of the gabbro epoch. It is hence possible that the Animikie gradually blended with eruptive debris and shaded off so easily into the Keweenawan that its upper limit will not soon be detected. However that may be, there was a great gabbro revolution, at a date somewhat later than the Animikie, which resulted in such alteration of the Animikie that, its characteristic debris being found in the Puckwunge conglomerate in the form of *red rock* pebbles, associated with white quartz and with fragments of Animikie slate, it is plain that a profound erosin interval was here interposed. It is this great gabbro revolution to which belong not only the great gabbro mass, mentioned above, but also its surface equivalents found further south, the chief of which is the great diabase mass which forms the summits of the Sawteeth mountains, named by Mr. Elftman Beaver Bay diabase. The centre of the gabbro mass being in the central part of the county, it superficially suffered a flowage toward the south, covering and fusing the Animikie, and reached the present shore line of lake Superior, and even continued within the deeper portions of the basin to a distance unknown. There seems to have been, at this date, one great uniform movement of a sheet of basic igneous rock which now extends from Duluth to the northeastern angle of Minnesota. Its thickness, as seen in the northward-facing bluffs of the Sawteeth range of hills, reaches several hundred feet. This surface movement carried along with it not only the superficial portion of the gabbro as it existed prior to the flowage, but enveloped and transported portions of the rocks over which it moved. In Lake county the Animikie strata were completely fused, and the acid rock thus formed united with the general movement, forming lavas which are often mixed confusedly with the basic. While this, in general, was the character of the translation toward lake Superior, there are many interesting facts of detail and many variations which unite to make the problem of the origin, history and relations of the gabbro one of fascinating geological interest, the full discussion of which will be found in the general chapter on Structural Geology (vol. v).

This great flow sheet was cotemporary with an extension of the gabbro into the unfused Animikie as dikes and sills, as seen in Cook county, and with the formation of diabase dikes in the older rocks along the northern border of the gabbro. With the lapse of time, and especially on account of the erosion of the glacial epoch, the surface connection between the parent gabbro mass and this great sheet has been broken, and the underlying red rock mass now separates them by a wide band that crosses the county. This red rock band embraces the sources of the streams of the county, whether they flow north or south, and it is therefore the most elevated part of the county; the moving gabbro flood must have had its thinnest parts along this red rock reef; this, in part, will account for the entire removal of the basic sheet over at least a portion of the red rock belt.

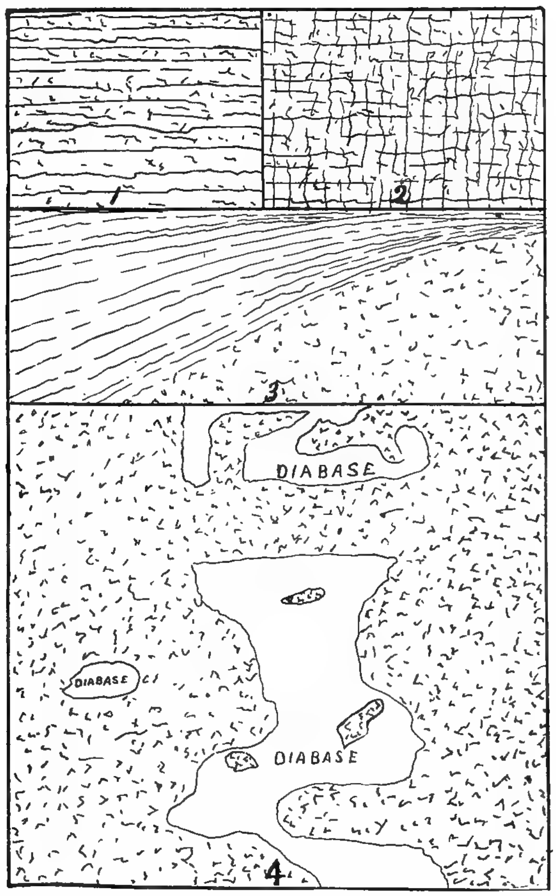


FIG. 41. ANORTHOSYTE AND ITS RELATION TO THE BEAVER BAY DIABASE, NEAR BEAVER BAY.

Peculiarities of the gabbro. Very interesting features of the gabbro, as represented by the Beaver Bay diabase sheet, appear at Beaver bay and at Splitrock river. The diabase surrounds isolated masses, often fifty or more feet in diameter, but usually less, of "feldspar rock," which present a strong contrast, in outward aspect, with the dark colors of the diabase. They are very common at Beaver bay, but some of the largest are at Splitrock point. They are also common and larger on

some of the diabase hills a mile or two back from the lake. Mr. Elftman's description of some of these knobs is as follows:

September 4, 1893. Going north on the county road which follows the section line between secs. 34 and 35 and secs. 26 and 27, T. 56-8, to the quarter post (probably the west quarter post of section 26), a peak 270 feet above the level of the quarter post rises on the way and causes the road to swing to the west. This peak rises in almost perpendicular walls 170 feet on the west side, but slopes more gradually towards the south and east. It bears about northwest and southeast and is about one-fourth of a mile long and one-eighth wide at the top.

The rock is the same as the anorthosyte seen at Beaver bay. It rises in snow-white knobs over the surface of the hill. The rock is cut by numerous small veins which weather to a pure white color (No. 1 of figure 41), Numerous small grooves cross the rock in one direction, having no definite and fixed direction in relation to the whole hill. Generally upon each knob the direction is different from that of its neighbor. Upon several knobs the grooves are cut by others running perpendicular to them (No. 2 of figure 41). This striation gives the rock a bedded appearance, when the striæ are parallel. Another form of this is a fan-like striation (No. 3 of figure 41). In this case the striæ appear to branch out from a centre and leave part of the rock unstriated. Rock No. 188aE, anorthosyte cut by veins; No. 188bE shows ordinary striation.

The sketches in figure 41 represent the structures described. No. 4 (of figure 41) shows the manner in which diabase (No. 398E) is distributed in the anorthosyte. The diabase appears to form the base of the hill, and the wandering dike is an offshoot from the main mass. It is somewhat finer grained at contact with the anorthosyte.

Near the section line (east line of section 27) and toward the northern edge of the hill the rock becomes somewhat darker as shown by No. 188cE. The anorthosyte here, although in some places composed entirely of feldspar without any accessory constituents, presents in other places the same variation in mineral constituents as seen in the gabbro farther north. On the north and west sides of the hill the rock is similar to gabbro and is composed of the usual proportions of augite, magnetite and fine-grained feldspar. The minerals have a tendency to collect in separate masses, each mineral by itself. This gives a peculiar mottled appearance to the rock upon its surface. When fresh the augite and magnetite form green and black spots (No. 188dE). These weather to a light yellow mineral (No. 188eE). Whenever these different minerals occur together they seem to have this peculiar combination. There are also parts of the rock in which the accessory ingredient is evenly distributed as shown by No. 188fE. Again, in some exposures on the southwest side of the hill, masses (not boulders) of pure feldspar are enclosed by a medium grained portion of the rock, like some gabbro, composed of feldspar, augite and magnetite in the usual proportion and evenly distributed. But the dark mineral is foliated and has a schistose appearance.

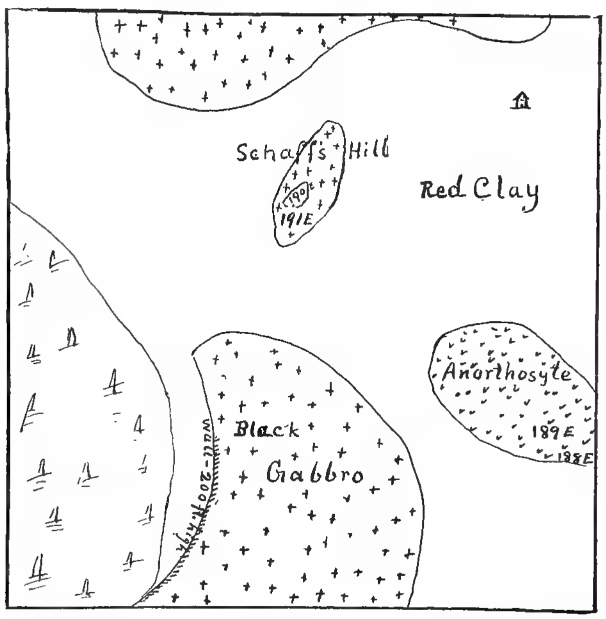


FIG. 42. ANORTHOSYTE KNOBS IN SEC. 27, T. 56-8, NEAR BEAVER BAY.

Near the centre of the top of the hill are several irregular dikes of black gabbro or diabase (No. 189E), which cut the anorthosyte and even enclose angular and rounded pieces of the same rock. Figure 41 shows this black gabbro dike.

Southwest of the above described hill is another elevation 120 feet higher than this. The rise is gradual from the town road to the S. E. ¼ of S. W. ¼ of sec. 27, T. 56-8, where an almost level piece of ground, one-

quarter of a mile across, forms the top. On the west side there is a perpendicular wall of black gabbro or diabase 200 feet high. The rock from this locality is represented by No. 199E. The rock, wherever examined, does not differ from the specimen taken. No trace of anorthosyte was found here. No exposures of rock were found on either side of the neck connecting the anorthosyte hill with the black gabbro hill, but it is most probable that the gabbro found cutting the anorthosyte is a part of the same rock which forms the hill farther southwest. This being the case, the anorthosyte rock is not in its original position, but is a mass transported by the black gabbro, perhaps separated from a larger mass.

North of the hill in the S. W. ¼ of sec. 27, T. 56-8, and one-quarter of a mile south of the north quarter post of the same section is a hill of about the same hight as the anorthosyte hill. It rises abruptly on all sides, and on the western side, about 150 feet from the top, it slopes gradually down to the swamp. Around the base the rock is the same black gabbro seen cutting the anorthosyte and forming the hill directly south of here (No. 191E). Upon the top and near the southern end of the hill is an outcrop of anorthosyte rock. This is a large boulder (?) 500 feet square on the upper surface. The anorthosyte (No. 190E) is composed of nearly pure feldspar for the greater part, but small areas, in which feldspar, augite and magnetite are evenly distributed, were also seen. This hill is known by the Beaver Bay people as Schaff's hill. [The "black gabbro" here mentioned is the Beaver Bay diabase.]

A map of section 27 containing these hills is shown by figure 42.

The shore of Beaver bay, from the red syenyte knob at the south point of the bay to the dark diabase at the northeastern, exhibits great variety and often confusion in the manner in which the red rock and the feldspar masses are associated, both being enclosed in the Beaver Bay diabase, but they can perhaps all be attributed to one general movement of the Beaver Bay diabase sheet. There are pebbles and boulders of the red rock embraced in the diabase, and the same red rock has the appearance of strings and veins and dikes cutting the diabase. It is in contact with masses of feldspar, crowded between it and the trap. The spots and masses of red rock are distributed, in some cases with pieces of the feldspar rock, throughout the trap, showing the accession of both ingredients when the trap was molten, and even contemporaneously. The feldspar rock varies in composition, becoming an ordinary gabbro, and the red rock varies from a quartz porphyry to a granitic syenyte. It was fluidized and runs about in belts and veins, not only through the diabase, but also through the feldspar rock.

At other points about Beaver bay, there are apparently two diabases, and it has been suggested by Mr. Elftman that one is a sill of later date penetrating the older basic sheets. But it is more likely that the finer diabase dikes that appear in the great sheet, and which are seen to cut the feldspar masses, are only apophyses from the uncooled deeper portions of the same sheet.

Suppose a great sheet of diabase, derived from the gabbro batholith, be put in motion over the strike of the Animikie. Its great body of heat and slow movement may be supposed to fuse the Animikie, and to incorporate portions of it. In the outward motion, especially wherever the surface of the diabase became solidified, the deeper molten portions would penetrate the cracks formed by shrinkage; and, when the diabase was not solidified, there must have been a contemporaneous fluidity, which would cause occasional intermixtures. If, as believed, the feldspar masses are segregations from the gabbro mass,* and, being a little lighter than the

*It will be observed that the gabbro and the diabase are considered essentially the same rock, derived and consolidated under differing conditions from the same magma. All petrographic facts known to the writer, and all structural features observed, when interpreted in the light of such a hypothesis, are consistent with such common origin of these rocks.

gabbro in general, were originally most abundant at the top of the gabbro batholith, they would have accompanied the diabasic flow in considerable numbers, and would have been subjected to the same incidents of consolidation and fracture, and hence to the formation of intersecting dikes of diabase, as the diabase sheet itself. Yet all these variations could be considered as incidental to the movement of one immense flow of igneous rock. At some points, especially in the area of the parent gabbro, near the line of contact with the red rock, the gabbro is frequently cut by the red rock, indicating the later date of the red rock, which is in keeping with the supposed origin of the red rock, and is largely owing to the greater ease with which, under aqueo-igneous fusion, siliceous magmas are transported; but the great flow sheet of the Beaver Bay diabase embraces considerable quantities of the red rock, and carried them along in a manner somewhat analogous to the transportation of the feldspar masses.

In townships 62-10 and 11, and 61-10 and 11, is an area of about two townships in extent of foliated olivine gabbro. Within this area are numerous knobs of feldspar rock as clear, fresh and coarse as the anorthosyte masses found near the lake Superior coast. In many instances the feldspar knobs appear like water-worn boulders enclosed in the overlying olivine gabbro.

On West Greenwood lake, T. 58-10, are extensive outcrops of fresh hypersthene gabbro. This is cut in several places by dikes of red rock which forms Greenwood mountain, south of the lake.

A point of importance, in studying the gabbro, as stated by Mr. Elftman, is that the gabbro along the centre of the formation has a belt in which are numerous knobs and areas a mile in extent composed of plagioclase rock similar to that mentioned above. In going from the northern or southern limits of the gabbro toward this belt, it is very noticeable that the ferro-magnesian minerals decrease and the feldspar increases in proportion. The rock has a more stratified appearance, arising from the arrangement of the constituent minerals in bands. This separation of the minerals, when carried to extremes, produces the large aggregations of feldspar.*

The muscovadyte. This rock occurs frequently at the northern border of the gabbro where the gabbro is in contact with the Keewatin. It is typically developed when the Keewatin is greenstone, and especially if it be some fragmental greenstone having a sedimentary structure. When the greenstone is more siliceous a pyroxenic gneiss is produced, as on the long point in Gabimichigama lake. There is no doubt that wherever this rock appears it is the result of contact of the gabbro on the Keewatin, and is apparently a step in the conversion of the greenstone into gabbro. If at the same place the greenstone embraced jaspilyte, it is altered to a

* A. H. Elftman. *Twenty-second Annual Report*, pp. 169, 170.

quartzose and olivinitic ore, and such deposits have already been noted under the heading *Muscovadyte and its iron ores.* There have been made numerous observations that demonstrate that frequently the gabbro with a coarse crystalline texture has covered angular pieces of the muscovadyte, and in those places that the gabbro in such form is of later date than the muscovadyte.

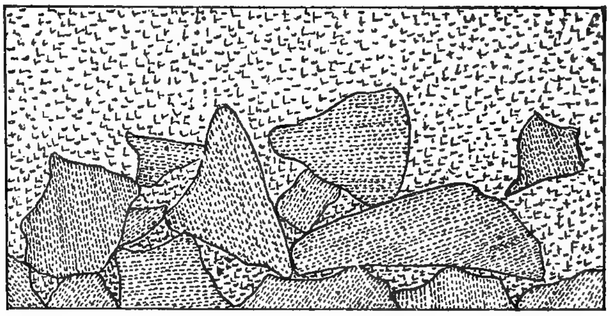


FIG. 43. GABBRO ON "MUSCOVADO" FRAGMENTS.
Island near the centre N. W. ¼ sec. 6, T. 64-5. Gabimichigama lake.

Still, there are numerous observations which indicate a close genetic relationship between the muscovadyte and the gabbro itself, and in these conditions it has been considered a phase of the gabbro. Structurally and petrographically it is in many places inseparable from the gabbro. There are considerable areas lying sometimes several miles south from the main northern border of the gabbro which are occupied entirely by muscovadyte, and in some of these instances the two rocks are closely intermixed and blended, and seem to be of cotemporary date. This intermixture is perhaps still more frequent along the northern limit of the gabbro where the muscovadyte is plainly derived from the Keewatin. It is this alliance with the igneous gabbro on one hand and with the greenstones of the Keewatin on the other that suggests the idea that the muscovadyte is a connecting stage in the formation of the gabbro from the Keewatin by a process of metamorphism and fusion, *i. e.*, by a force identical with that which metamorphosed and fused the other (acid) Archean rocks, producing granite, syenyte, dioryte, etc., as already indicated.

Note. On visiting again, October 6, 1898, the Cheadle iron locality, south side of Disappointment lake, the following facts were carefully noted:

1. The ore is in bedding that dips about 80° toward the south.
2. The dip of the formation in which it occurs is the same.
3. The formation is that seen at the lake shore and westward further, passing into the bouldery greenstone seen at the southwest end of Snowbank lake.
4. The ore, therefore, is in a bouldery greenstone which, in this area, is placed in the Lower Keewatin.
5. The ore is in several bands, one of them being further south than the real gabbro border.

6. Where it occurs in this most southern band it is a coarse conglomerate, evidently also a phase of the greenstone formation.

7. The quartzose ore bands alternate with gabbroid bands containing coarsely crystalline hypersthene (?).

8. In small amounts there is a similar ore in the gabbro.

9. The ore hence probably resulted from an alteration of jaspilyte in the Keewatin.

10. The pebbly and bouldery muscovadyte is conspicuous as muscovadyte, in most places from the lake shore to the iron ore.

11. It gradually loses its fine grain going south.

12. As it acquires a coarser grain the bouldery forms become less and less distinct.

13. The gabbro contains boulders, generally much like the muscovadyte, even when the rock has become coarsely gabbroid, and these are in some cases as large as six or eight inches.

14. In some cases such boulders are not of muscovadyte but are quite siliceous, as if originally granitoid.

15. The bouldery iron ore further south is permeated and enclosed by coarsely crystalline gabbro, but in general forms, apparently, a belt about ten feet thick that runs as if in place.

16. The gabbro in places forms abrupt contacts on the muscovadyte.

17. As to the pebbles, whether in the muscovadyte or in the gabbro, they are much altered, tending to become muscovadyte in both rocks—at least in the muscovadyte they are less altered than in the gabbro. As a fact, they are not very common, as conspicuous foreign masses, in the gabbro, but seem to be lost in the gabbro. Yet sometimes, over a weathered surface of gabbro, may be seen roundish areas, either coarser or finer grained than the average, and these are probably due to differing pebbles whose composition responded with varying readiness to the transforming force which, in general, resulted in the gabbro mass.

It may be added, that there is some doubt as to the separateness of this conglomerate from that which is cut extensively by the Snowbank Lake granite, and which is considered as Upper Keewatin.

There have been made a multitude of detailed observations on the field appearances of the gabbro in Lake county, the most of those by Mr. Elftman never having been published. He has summarized the results in a paper in the American Geologist (vol. xxii, pp. 132–149), but the rock numbers and all special descriptions are designed to be included in the twenty-fourth report of the survey.

The red rock, as it appears in the west bluff of Beaver bay, is represented by rocks Nos. 124 and 625. It appears like a red granite, but consists of a confused compound of quartz and feldspar, the greater part of the latter being orthoclase, and

FIG. 1. LENTICULAR INCLUSION OF QUARTZ PORPHYRY IN GABBRO, SOUTH SIDE OF THE NORTHEAST POINT OF BEAVER BAY. (pp. 305, 309.)

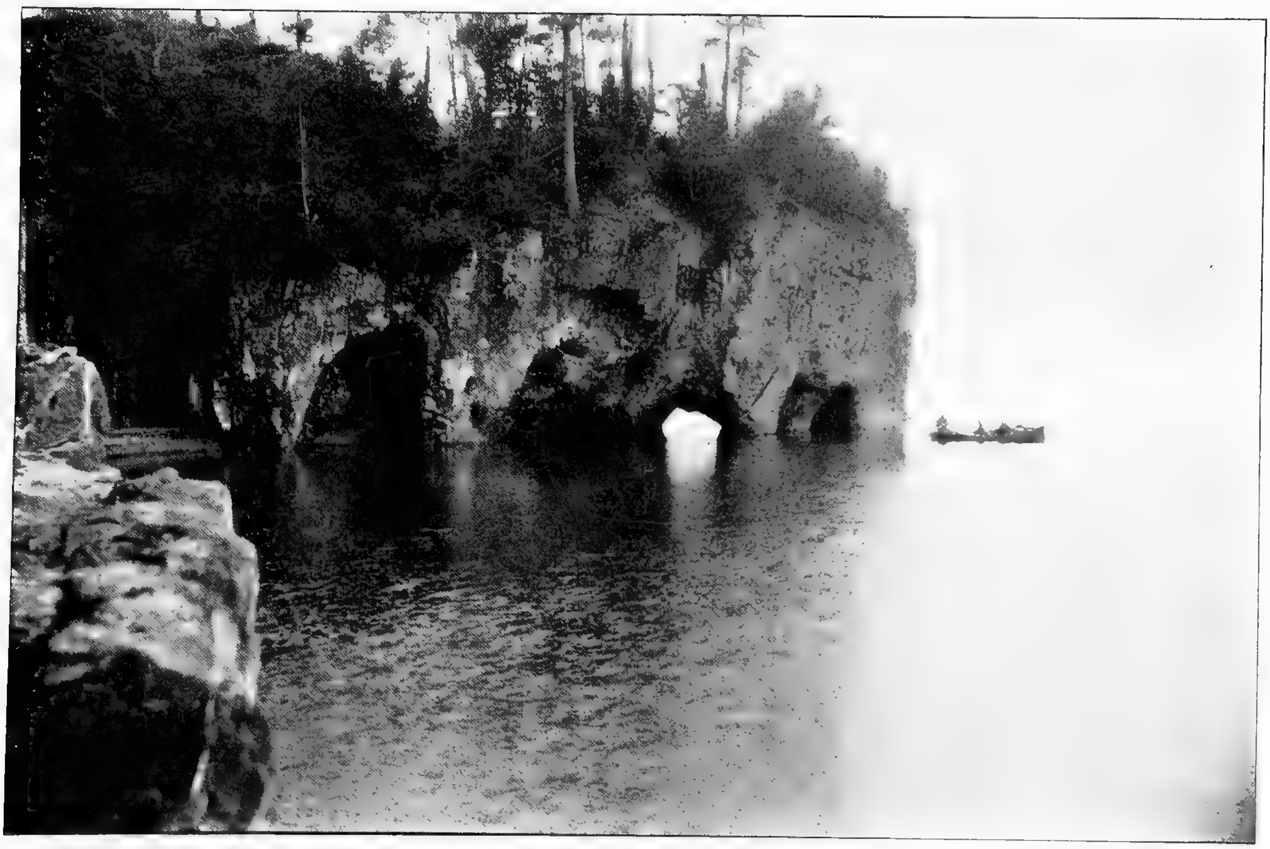


FIG. 2. NATURAL ARCHWAY AT THE POINT OF THE GREAT PALISADES.

reddened by ferric oxide. The quartz and orthoclase are united sometimes in a micro-pegmatitic or micro-poikilitic manner, but in general they have confused and ill-defined relations. A reddened felsitic matter permeates and clouds much of the quartz and all of the feldspar. With a trace of a ferro-magnesian mineral, now in the form of chlorite, and an occasional grain of some iron ore, pyrite or magnetite, this rock differs from the finer apobsidians of the red rock series only in having reached a more advanced stage of crystallization before consolidation. The more rhyolitic forms are more common, and constitute the pebbles of the lake beach so abundantly that sometimes for several miles the beach presents a pinkish red color. Such rock is also more abundant inland.

At West Greenwood lake are numerous dikes of the red rock cutting the gabbro, and the red rock forms extensive outcrops south of the lake. Greenwood mountain is a mass of fiery red red-rock of rather fine grain, not rhyolitic, the quartz in isolated masses, but having a common orientation over large areas. In some places a plain rhyolitic structure prevails, and when the color varies with the bands the rock presents a handsome appearance. Such aspect occurs near the Beaver Bay trail in S. E. $\frac{1}{4}$ sec. 33, T. 58–10, on the south side of the broad ridge. Here the rock varies to almost black, and probably is affected by assimilation of diabasic elements from the gabbro. Such assimilation goes so far sometimes that the rock is a mixture of the acid and the basic minerals. But whatever the variations in color or in crystalline condition, the red rock as a body is distinct from the diabases and can be traced almost continuously across its entire width, and, with interruptions, to the red rock at Beaver bay. It is sometimes cut by diabase dikes, but it is difficult or impossible to determine their relative ages, although believed to be, as a mass, in its original genesis of later date than the great sheet of Beaver Bay diabase, though partially enclosed in it and permeating it at a later period (plate DD, figure 1).

Relations of the red rock and gabbro. Dr. Grant made an examination of the country from lake Polly, which is in T. 63–6 W., into the next town south. Gabbro was seen along the river and lake in many places, in N. W. $\frac{1}{4}$ sec. 34, T. 63–6 W. It is quite coarse grained, and is cut by branching vein-like dikes of red granite. These are from half an inch to ten feet across and run in every direction, not noticeably finer-grained at the surfaces contacting on the gabbro than at the centres (No. 755G). It consists of a fine-grained, pinkish biotite granite, the biotite being in comparatively small amount. A short distance further east these dikes become very numerous, composing about one-third of the gabbro, where it outcrops. Still further east, in secs. 34 and 35, T. 63–6 W., granite dikes are not so numerous.

The shores of a small lake about* in sec. 2, T. 62–6 W., show outcrops of coarse-grained gabbro sometimes cut by small granite dikes.

*Locations cannot be given exact, since this township has not been subdivided by the U. S. government.

At Syenyte lake, which is about a mile and a quarter southeastward from the last mentioned lake, gabbro occurs associated with a fine-grained dioryte at a short distance north of the lake. The gabbro is very coarse-grained and is composed largely of feldspar. The dioryte is much finer (No. 756G), dark gray and contains quartz and is sharply separated from the gabbro by distinct contact lines. Dikes of dioryte were not seen in the gabbro, but angular fragments of the gabbro of various sizes and shapes occur in the dioryte. Red granite dikes up to twenty feet in width cut both gabbro and dioryte with sharply marked dike walls. The dioryte in thin section shows a granitic aggregate of plagioclase, hornblende, quartz, magnetite and pyroxene, the last in small scattered grains which usually have rounded outlines.

The shores of Syenyte lake, so far as examined, are divided between red granite and gabbro, the latter represented by No. 757G. This rock is even coarser-grained than usual. The granite is a hornblende granite of fine but rather uniform grain, varying in color from almost white to brick red (Nos. 758G to 763G).

From these observations, thus abbreviated from the Twenty-fourth Report Dr. Grant concluded that the evidence is conclusive that the granite is later than the gabbro. The main granite mass can in some cases be continuously traced into some of the apophyses that penetrate the gabbro, and these continue as dikes of greater or less frequency for a distance of several miles into the gabbro area, sometimes five miles from the general limit of the gabbro. The dikes are not finer grained, as a whole, nor near contact with the gabbro, than the rock of the main mass, this indicating the heated condition as well as the deep-seated position of the gabbro at the time of the intrusion of the dikes. Still, the sharp edges of the dikes, and the rare mingling of the elements of the two rocks, indicate that the granite, while perhaps not much younger than the gabbro, was of later date than the solidification of that rock. In other areas there are facts which seem to indicate that the two rocks were molten at about the same time.

At Baptism river and at the "Great Palisades" the red rock makes characteristic outcrops (Nos. 139, 140, 154). At the former locality a sharp, sloping, rocky point projects into the lake with a perpendicular face toward the south, the red rock lying on a series of trap rocks consisting of amygdaloidal basic surface flows. Up Baptism river is a conglomerate of pebbles largely from this rock (No. 149). The Great Palisades have a total altitude of 315 feet, the highest perpendicular wall rising out of the lake is 210 feet. At the water level the red rock comes into superposition on a diabase and exhibits a varied lithology (No. 140). It is by the easier erosion of this part that the face of the Palisade bluff gradually recedes inland. As they become unsupported, column after column of the bluff slides down perpendicularly

and generally breaks into large blocks which remain and make a breakwater protecting the lower beds from the force of the waves and ice; but sometimes they remain standing partially erect and unbroken, after sliding down, leaning against the bluff. One could be seen standing in 1878, when this examination was made, about twenty-five feet long.

The immediate coast line, with geological designations, is represented on plate FF.

The Manitou series. This name is intended to cover that part of the eruptive Keweenawan which followed the great gabbro revolution. The fragmental base is a pebbly conglomerate which embraces debris from the altered Animikie, as well as Animikie slates unaltered, red rock, quartz and quartzyte. This rock, which is named *Puckwunge conglomerate* from the stream on whose southern bluffs it appears conspicuously in Cook county, is supposed to be represented in Lake county by a red-rock pebbly conglomerate seen in outcrop a short distance up the Baptism river, at one-half mile below the first falls. Some of the pebbles are six inches across (No. 149). Still, this conglomerate is sometimes finer, and even shaly, indicating a supply of red eruptive material, not entirely in keeping with the nature of the basal conglomerate at other points. These shaly outcrops appear, therefore, to be in some of the upper horizons of the conglomerate, which is known to be accompanied at other places, as at Grand Portage island, by cotemporary lavas. Such lavas gave rise to a loose and red conglomerate, often mingled with laumontitic zeolites, as seen at the mouth of Manitou river. The Baptism river conglomerate is also in outcrop at the coast at three-fourths of a mile east of Baptism river, where it rises thirty feet, and is hardened and altered much by a diabase dike twenty feet wide (No. 155A). The Manitou series accompanied and followed the Puckwunge conglomerate.

The diabases which succeeded the Puckwunge conglomerate, alternate with amygdaloidal partings, and sometimes with sandstones. The total thickness of these diabases cannot be given, but they probably reached several hundred feet. They are well seen with associated fragmentals at Little Marais, and for a mile westward, at Gooseberry river and along the coast to the western limit of the county. These sandstones, even when conglomeratic, differ from the basal conglomerate so profoundly that they need not be confounded with it.

There are also many diabase dikes which penetrate even the latest surface lavas known in Lake county, and according to Mr. Elftman a large spur of the same enters the county from Cook county, crossing Ts. 60–6 W. and 60–7 W.

There are seven layers of trap alternating with loose, sometimes brecciated, amygdaloidal layers, visible in rounding the point from Agate bay to Burlington bay, and five in entering Agate bay from the west. The dip is generally toward the

lake. Along the point east of Burlington bay a similar succession of trap and amygdaloid layers from six to twenty feet thick are seen, dipping in the same direction toward the lake; but near the extremity of the point is a remarkable instance of a heavy trap layer supported for a long distance on buttresses of amygdaloid standing between deep and dark purgatories. The trap bed is about ten feet thick, and the whole rises twenty-five or thirty feet gradually from the lake level, the amygdaloid being about fifteen feet thick and resting on another trap bed which, further on, either east or west, also rises from the lake with a similar dip, but without forming a long bridge. This bridge is destitute of trees, and at a distance somewhat simulates a large and heavy railroad bridge. There are thirteen caverns, separated by natural buttresses. The reader may compare the general plate showing the lake Superior shore (plate FF).

The lake shore in Lake county. The first work done in the study of Lake county was along the shore of lake Superior in 1878.* Numerous rock samples were collected, most of them now thin-sectioned and reported more in detail in their petrographic characters in vol. v of this report. At the same time sketches and a few photographs were made, and some of these are used to illustrate this and other chapters.

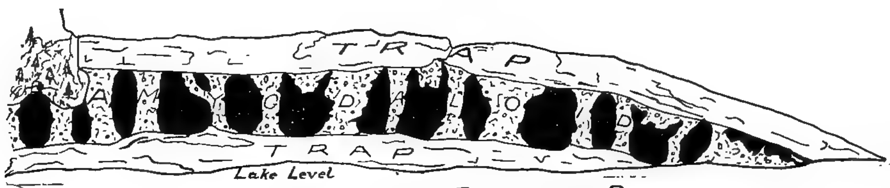


FIG. 44.

The eastern shore of Burlington bay and the point are constructed, like the shores of Agate bay, of alternating layers of soft and hard rock, the whole more or less igneous or vesicular. Near the extremity of the point is a remarkable instance of a heavy trap bed supported on buttresses (figure 44) of softer amygdaloid which separate deep and dark purgatories to the number of thirteen. The trap bed, which lies like the superstructure of a bridge on piers, is about ten feet thick, and the whole rises twenty-five or thirty feet toward the west, but descends gradually to the lake level toward the east.

Some illustrations have been given of the manner of distribution of the feldspar masses in the diabase at Beaver bay, and some descriptions by Dr. Elftman.

Along the shore of Beaver bay are unsurpassed facilities for studying the relations of these two rocks. Dr. Lawson has given some photographs of the same in Bulletin X, and some of his views are also reproduced in plate CC. Some field sketches by the writer are seen in figures 44, 45 and 46. The first repeats the fact, represented

* Detailed field descriptions are published in the Ninth and Tenth Annual Reports of the survey.

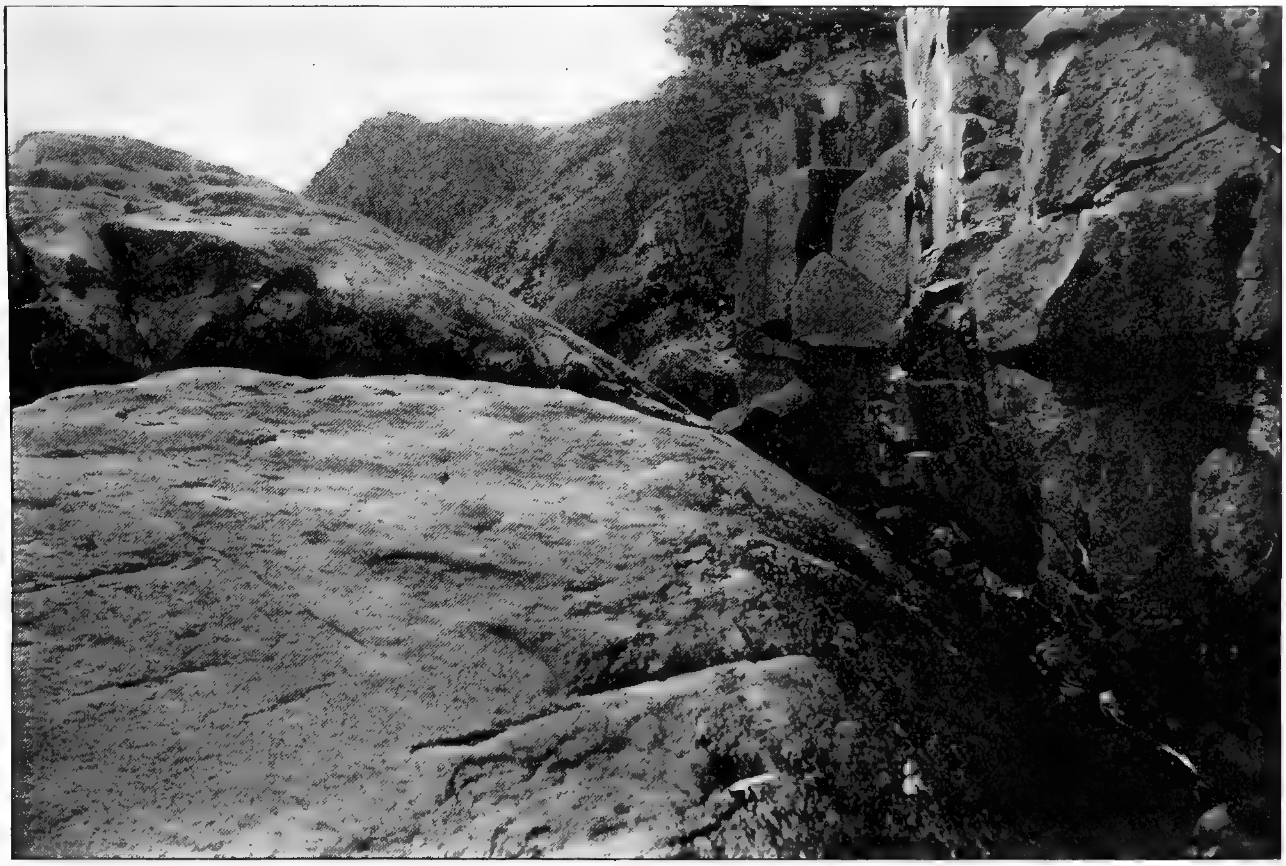


FIG. 1. ROUNDED SURFACE OF LARGE MASS OF ANORTHOSYTE OVERLAIN BY DIABASE. BEAVER BAY. (p. 308.)

FIG. 2. GROUP OF SMALL MASSES OF ANORTHOSYTE IN DIABASE. (p. 308.)

by Dr. Elftman, that the feldspar masses are intimately associated with the diabase in such a manner that their shapes are materially modified by the diabase, sometimes penetrating them in apophyses and in isolated areas. The second shows a basaltic trap mass which evidently transported a large feldspar block. In cooling, the trap did not acquire a columnar structure, vertical against the feldspar mass, as it prob-

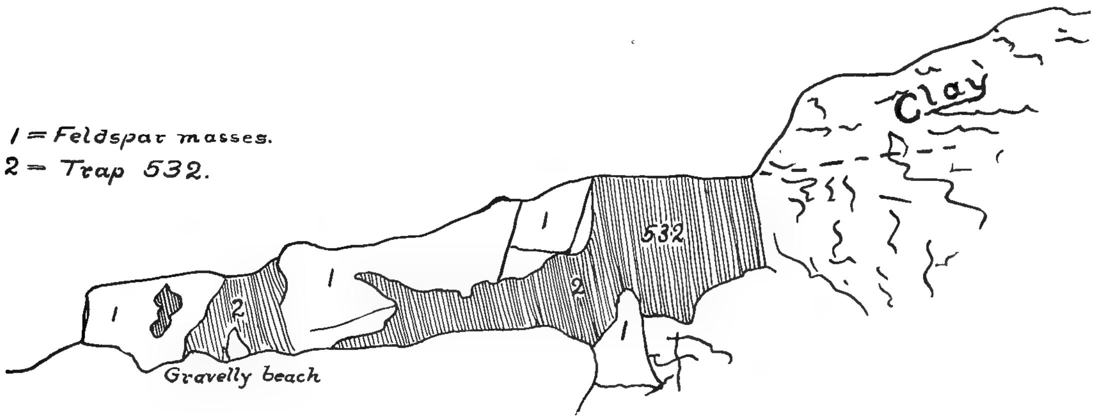


FIG. 45. POINT OF ROCK IN BEAVER BAY.
North of the mouth of the creek.

ably would had the feldspar mass been a cold and earlier rock, but its columns are vertical against the lower rock surface, shown in figure 47. The feldspar, therefore, seems to have been as hot as the trap itself, though not so mobile. It will be noticed, also, that the same trap carries a piece of red granite, seen near the water-level. Such red rock, more frequently in the form of quartz-porphyry or aporhy-

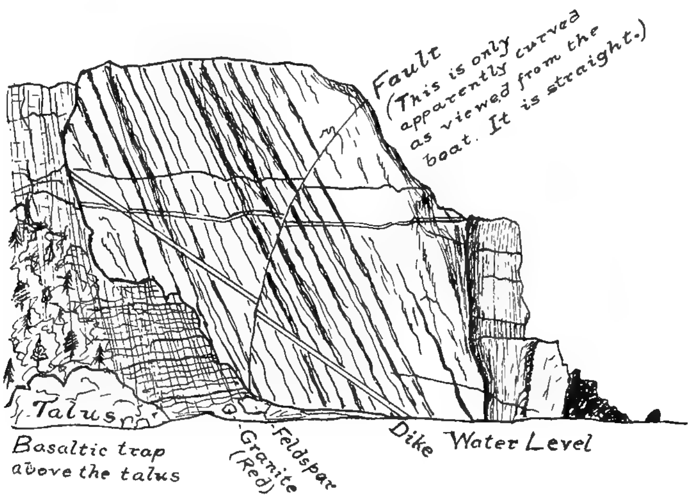


FIG. 46. FELDSPAR BLUFF.
First east of Two Harbor bay, looking east.

olyte, is quite abundant in a few localities in the trap of Beaver bay. A lenticular mass in this trap is shown by plate DD, figure 1.

Figure 47 represents a more general succession of parts at Two Harbor bay.*

*This is a small bay a short distance west of Beaver bay. and should not be confounded with the ore-shipping port of Two Harbors. The latter bay, in this report, is known by its old name, *Agate bay*.

This sketch shows a westward continuation of the basaltic sheet seen in figure 46, but the feldspar mass is not the same.

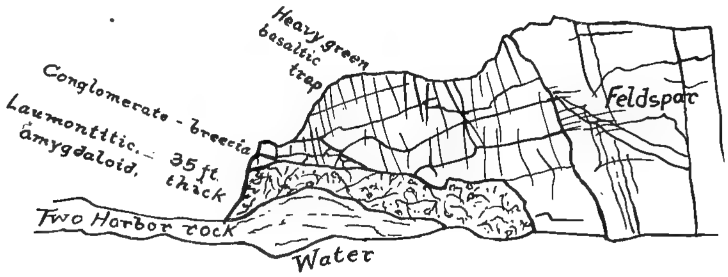


FIG. 47. ALTERNATION.
At the first high point east of Two Harbor bay.

The sandstones that succeeded the basal (Puckwunge) conglomerate alternate with the upper part of the Manitou traps, and gradually prevail over the traps. They finally are entirely free from trap sheets. It is likely that vegetation and other

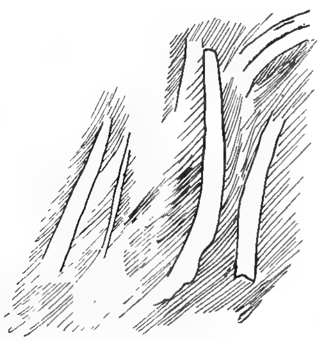


FIG. 48. MARKS OF VEGETATION SEEN ON A SOMEWHAT SANDY SLAB OF RED SHALY AMYGDALOID ON THE BEACH AT FLOOD BAY, OCTOBER 19, 1881.

organic forms slowly occupied the shallow waters. This is indicated by the faint vegetable traces seen on a sandstone slab and sketched in figure 48. Flood bay is near the mouth of Stuart's river.

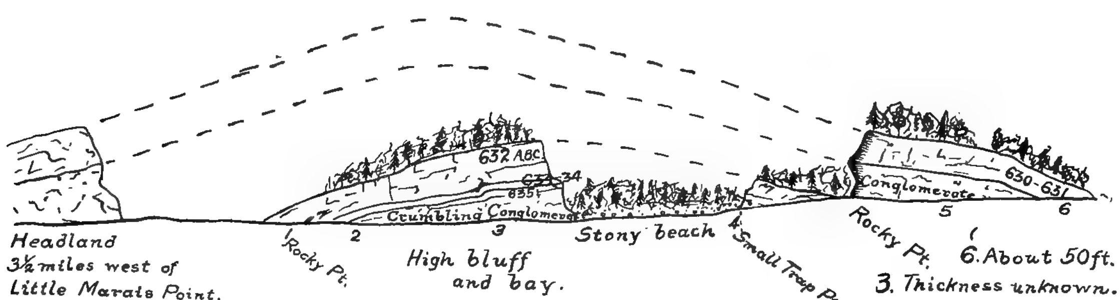


FIG. 49. SUCCESSION OF CONGLOMERATES WEST OF LITTLE MARAIS.

These upper sandstones and crumbling conglomerates into which the Puckwunge conglomerate seems to graduate appear abundantly along the coast westward from Little Marais, where they alternate with layers of common diabasic trap (Nos. 630–635), as shown by the sketch, figure 49.

The same trap-sheet seen in figures 46 and 47 continues further eastward, and its relations are seen again in figure 50, where it is seen to lie on a breccia similar to that seen in figure 47, and to pass below a large mass of red granite.

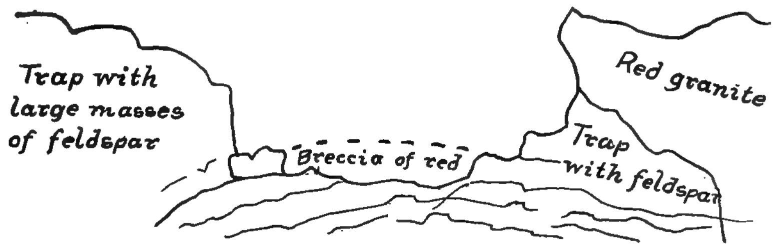


FIG. 50. FIRST AND SECOND HIGH POINTS EAST OF TWO HARBOR BAY.

A general view of the outline of the Great Palisades is shown by figure 51. This rock is in general a reddish aporhyolyte, varying to apobsidian and to quartz porphyry, having a confused vertical columnar structure. It is represented by rocks Nos. 138, 139 and 140, and appears at several other points on the coast further west and at the mouth of Baptism river. The altitude of the perpendicular bluff near

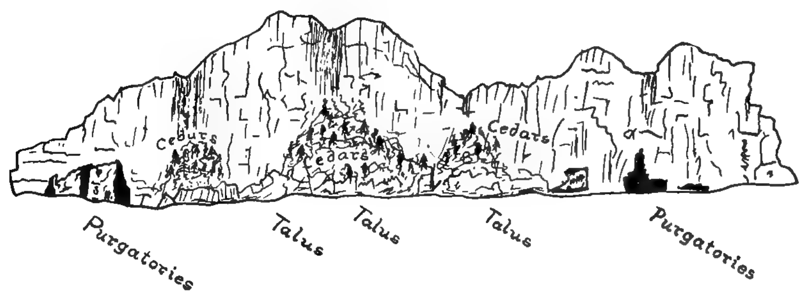


FIG. 51. THE GREAT PALISADES.

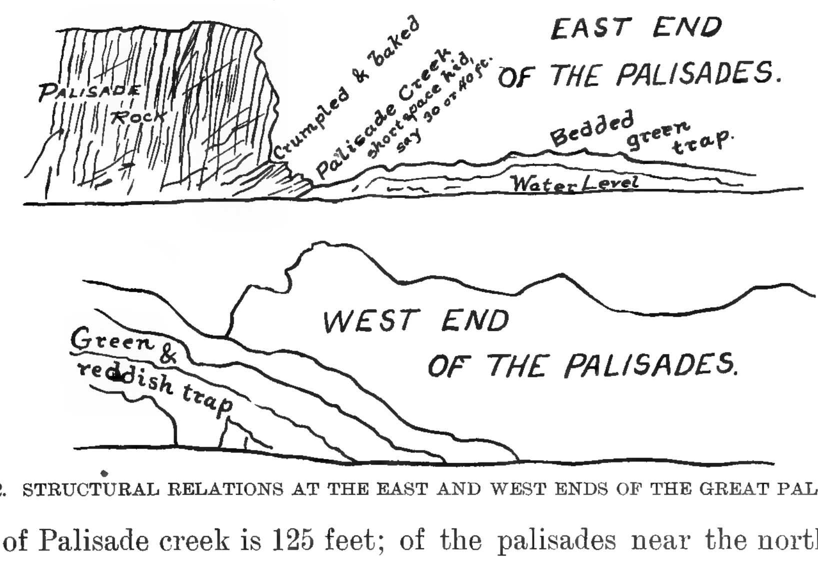


FIG. 52. STRUCTURAL RELATIONS AT THE EAST AND WEST ENDS OF THE GREAT PALISADES.

the mouth of Palisade creek is 125 feet; of the palisades near the north line of section 28, back of the bluff, 145 feet, separated from the main palisades by a slight depression. The highest point of the palisades is 315 feet; highest perpendicular over the lake, 210 feet. This is an isolated mass, which breaks away immediately

back from the lake shore, the lower country being occupied by the prevailing green trap of the region.

The Great Palisades condense the moisture that rises from the lake in a southerly wind, and a mist is much of the time about their summit. The bare rock all over the top is covered by a thick cushion of moss, which is supported by this moisture.

That the palisade rock is one of the series of surface flows of lava during the Keweenawan is shown by the nature of the rock as well as by the relations it bears to the trap at the east and at the west, where it is seen to overlie some of the trap sheets.

In figure 53 it is represented as penetrated by dikes and curved sheets of trap which has a basaltic structure perpendicular to the surfaces of the palisade rock.

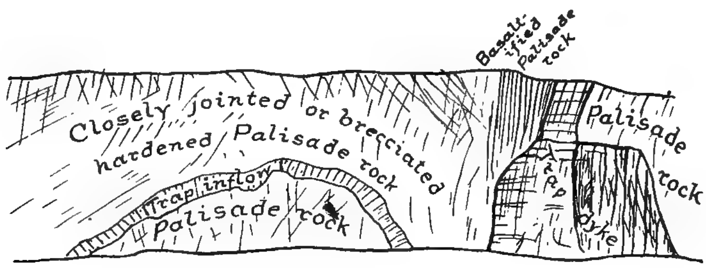


FIG. 53. PALISADE ROCK.
About one and one-half miles west of the Great Palisades.

Figure 54 shows the manner in which Gooseberry river is choked by beaches; and the profile of the Keweenawan trap-sheets, through which it has maintained a channel. The rock (No. 518) embraces a great many agates.

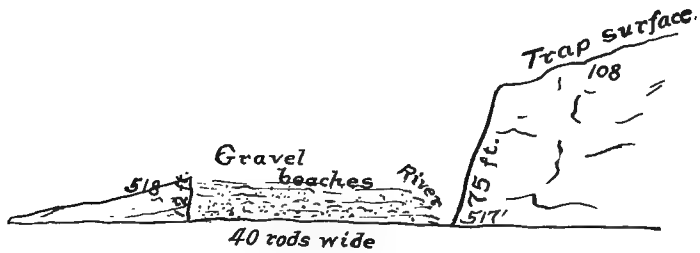


FIG. 54. MOUTH OF GOOSEBERRY RIVER.

Rock samples collected in Lake county. By referring the following rock numbers to the petrographic descriptions in another part of this work, much detail of the characters of all the rocks of the county will be found:

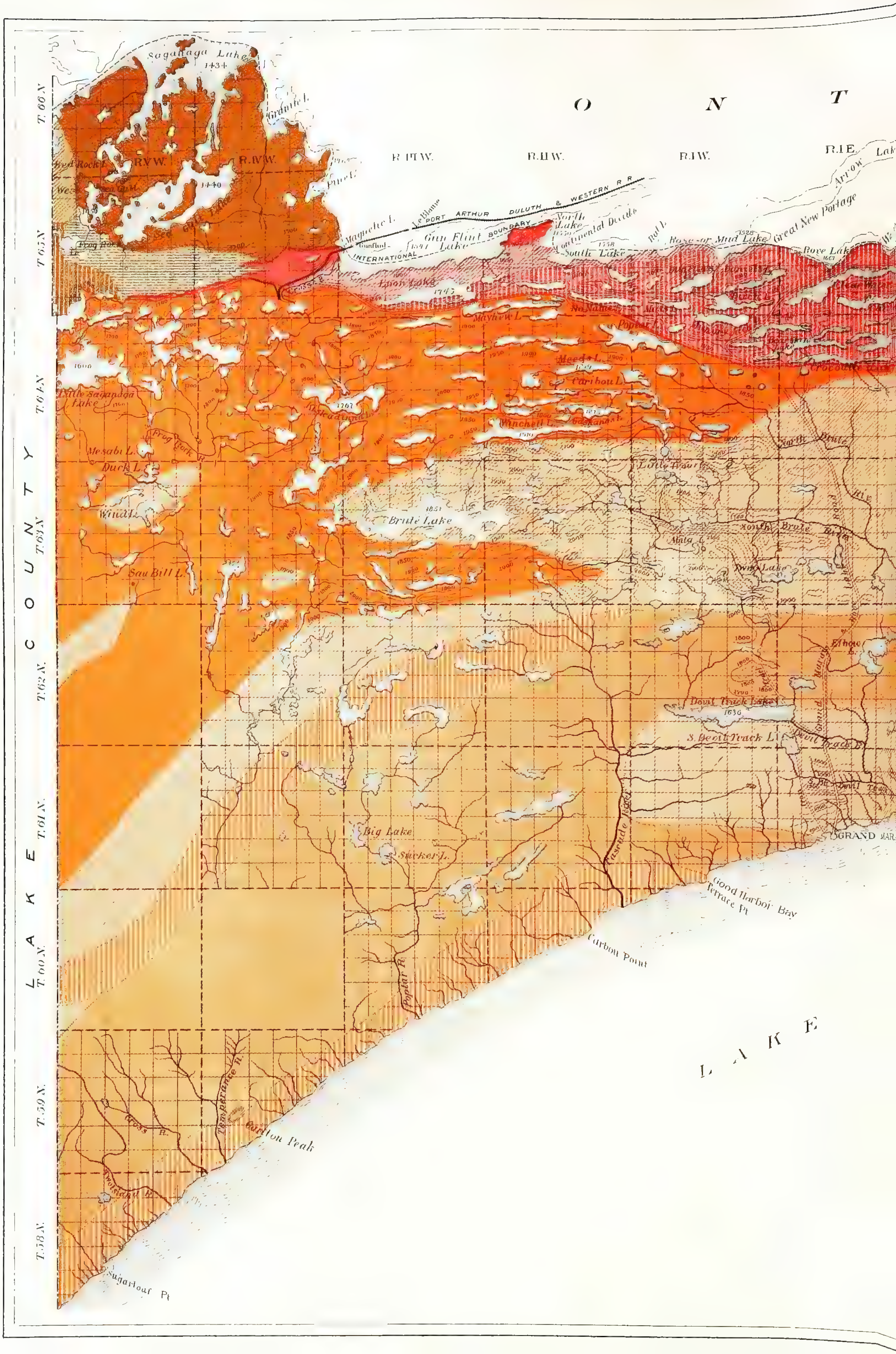
Nos. 92–162; 322-356; 517–534; 628–640; 738–766; (767 and 768 are also probably from Lake county); 810–819; 948–951; 954; 979–1000; 1017–1070; 1073–1087; 1093–1127; 1361–1379; 1385–1446; 1709; 1715–1771; 2030½; 2145–2274.

Nos. 93W–106W; 126W–135W; 138W–151W; 174W–281W; 294W–382W; 524W–569W; 887W–987W.

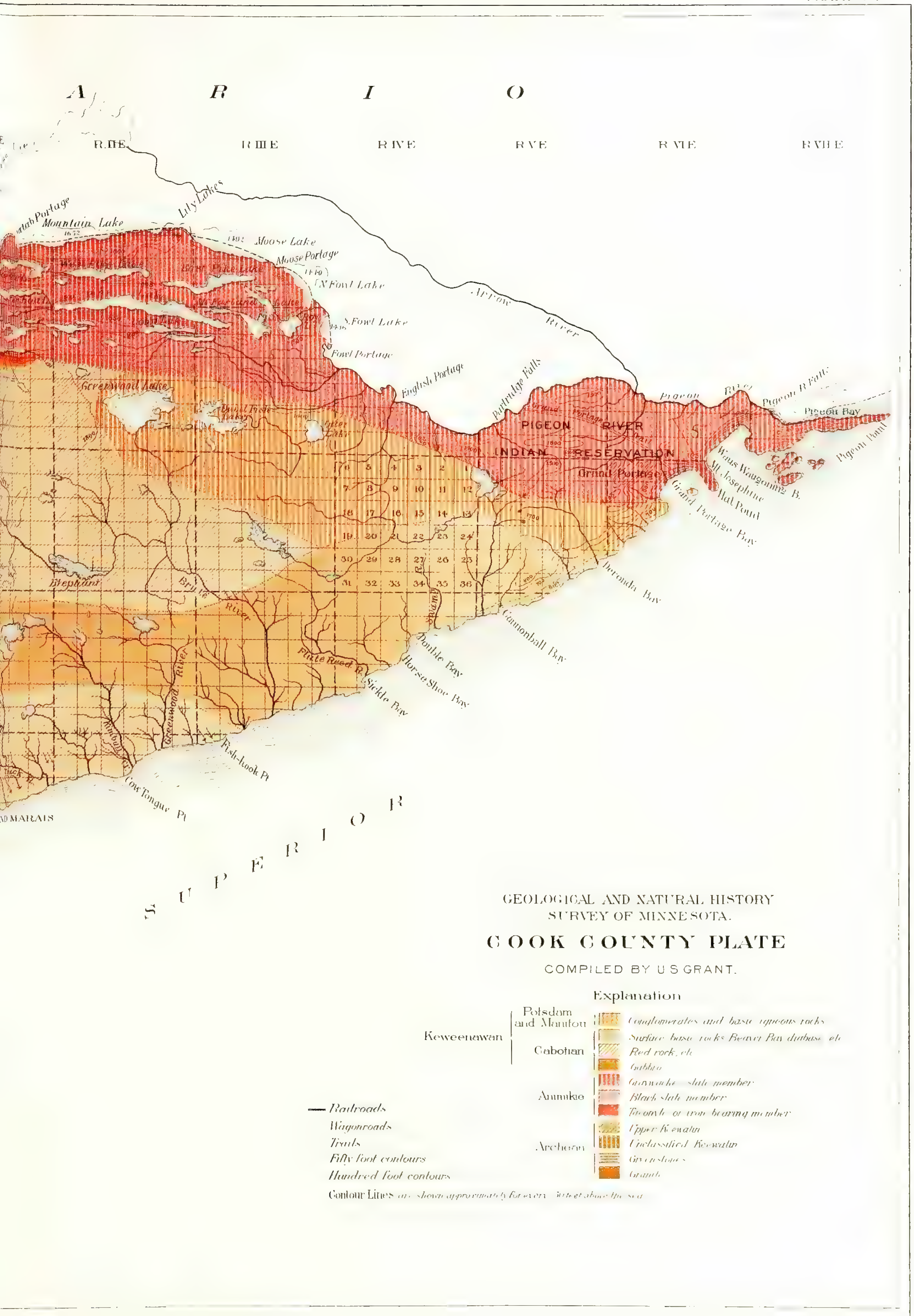
Nos. 30H–74H; 407H–417H; 420H–432H; 458aH; 461H–542H.

Nos. 1G–5G; 68G–114G; 128G; 132G–169G; 245G–277G; 299G–644G; 690G–700G; 711G; 727G–820G; 840G–845aG; 850G; 853G–854aG; 1068G; 1069G.

Nos. 27E–138E; 146E–150E; 152E–186E; 188E–228bE; 260E–263E; 266E–290E; 351E–425E; 572E–637E; 697E–767E.



Saganaga Lake
1434
O N T
R.V.W.
R.IV.W.
R.III.W.
R.II.W.
R.I.W.
R.I.E.
PORT ARTHUR DULUTH & WESTERN R.R.
INTERNATIONAL BOUNDARY
Gun Flint Lake
North Lake
South Lake
Rose or Mud Lake
Great New Portage
Arrow
Rove Lake
Loon Lake
Mayhew L.
Meeds L.
Caribou L.
Winchell L.
Little Saganaga Lake
Mesabi L.
Duck L.
Brule Lake
Sau Bill L.
North Brule
South Brule
Twin Lake
Elbow L.
Devil Track Lake
S. Devil Track L.
GRAND MAR
Big Lake
Sucker L.
Good Harbor Bay
Terrace Pt
Carbon Point
Poplar R.
Temperance R.
Cross R.
Carlton Peak
Sugarloaf Pt
L A K E
L A K E C O U N T Y
T.66N.
T.65N.
T.64N.
T.63N.
T.62N.
T.61N.
T.60N.
T.59N.
T.58N.


R II E
R III E
R IV E
R V E
R VI E
R VII E
Mountain Lake
Lily Lakes
Moose Lake
Moose Portage
N. Fowl Lake
S. Fowl Lake
Fowl Portage
Arrow River
English Portage
Partridge Falls
Greenwood Lake
Pigeon River
Pigeon R. Falls
Pigeon Bay
Pigeon Point
PIGEON RIVER INDIAN RESERVATION
Grand Portage
Waus Waugoning B.
Mt. Josephine
Hat Point
Grand Portage Bay
Elephant
Brule River
Deronda Bay
Cannonball Bay
Double Bay
Horse Shoe Bay
Flute Reed R.
Sickle Bay
Fish-hook Pt.
Cow Tongue Pt.
Greenwood River
GRAND MARAIS
S U P E R I O R
GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.
COOK COUNTY PLATE
COMPILED BY U.S. GRANT.
Explanation
Keweenawan
Potsdam and Manitou
Cabotian
Animikie
Archean
Conglomerates and basic igneous rocks
Surface basic rocks, Beaver Bay diabase, etc.
Red rock, etc.
Gabbro
Graywacke – slate member
Black slate member
Taconyte or iron bearing member
Upper Keewatin
Unclassified Keewatin
Greenstones
Granite
Railroads
Wagonroads
Trails
Fifty foot contours
Hundred foot contours
Contour Lines are shown approximately for every 50 feet above the sea

CHAPTER XII.

THE GEOLOGY OF COOK COUNTY.*

By U. S. GRANT.

Situation and area. Cook county (plate 69) is the extreme eastern and northeastern county in Minnesota. It has approximately the form of an isosceles triangle whose base is its western border. The county is bounded on the north and east by Ontario, on the south and east by lake Superior, and on the west by Lake county. The extreme length, east and west, of Cook county is about seventy-two miles, and its extreme breadth about fifty-four miles, while the total area is 1,680.4 square miles, of which 1,406.84 are land and 273.56 water.†

SURFACE FEATURES.

Natural drainage. Cook county lies in two great continental drainage basins, that of Hudson bay, and that of the gulf of St. Lawrence. The area which belongs to the first basin is confined to the northwestern part of the county and comprises not more than one-eighth of the total area of the county. On the international boundary the divide between the two great drainage basins is between South and North lakes, the latter of which lies in the Hudson Bay basin. From this point the

*The material for this chapter has been collected largely from the following sources: N. H. WINCHELL, field work of 1878, *Seventh Annual Report*, pp. 9-25, and *Ninth Annual Report*, pp. 42-85; field work of 1879, *Tenth Annual Report*, pp. 42-48, 56-61, 64-90, 98-106; field work of 1886, *Fifteenth Annual Report*, pp. 372, 378-381; field work of 1887, *Sixteenth Annual Report*, pp. 60-95, 98; field work of 1892, not published; field work of 1893, not published; field work of 1896, published in part in *Amer. Geol.*, vol. 20, pp. 50, 51, July, 1897, and in *Twenty-fourth Annual Report*, pp. 48-?. A. WINCHELL, field work of 1886, *Fifteenth Annual Report*, pp. 171-172; field work of 1887, *Sixteenth Annual Report*, pp. 211-314, 352-363. H. V. WINCHELL, field work of 1888, *Seventeenth Annual Report*, pp. 104-111. U. S. GRANT, field work of 1888, *Seventeenth Annual Report*, pp. 151-161, 168-186; field work of 1891, *Twentieth Annual Report*, pp. 83-95; field work of 1892 and 1893, *Twenty-fourth Annual Report*. A. C. LAWSON, field work of 1891, *Twentieth Annual Report*, pp. 181-289, and *Bulletin* 8, pp. 1-48. C. P. BERKEY, field work of 1893, *Twenty-second Annual Report*, pp. 134-140; A. H. ELFTMAN, field work of 1895-1897, published in part in *Amer. Geol.*, vol. xxi, pp. 90-109, 175-188; vol. xxii, pp. 131-149.

The examination of this county has been confined largely to the vicinity of the lake Superior shore and the international boundary, along the latter of which the examination has usually been carried as far south as the south side of township 65. In addition to the above may be mentioned the following routes of preliminary reconnoissances in the interior of the county: (1) From Gabimichigama lake, at the southwest corner of T. 65-5 W., south-southeastwardly through Little Saganaga, Mesabi, Duck, Wind and Sawbill lakes to the Poplar river and along this stream to its mouth, in sec. 34, T. 60-3 W. (2) From Gunflint lake south through the lakes in T. 64-2 W. to Brulé lake, and then northward through the eastern parts of Ts. 63-4 W. and 64-4 W. (3) From Grand Marais through Devil Track, Abita, Little Trout, Misquah, Cross and Poplar lakes to Gunflint lake. (4) Along the Grand Marais and Rove Lake road. (5) Through the lakes in the northern part of T. 64-2 E. and southeast by McFarland's trail to lake Superior at Horseshoe bay. (6) From Grand Portage village westward to the lakes near the northwestern corner of T. 63-5 E. (7) Along the Grand Portage trail.

This chapter can in no sense be considered a detailed and final account of the geology of this county, for the information at hand will not warrant such an account, and, moreover, the time allowed for the preparation of this chapter will not permit of a full presentation of the details at hand. Considerable detailed information is given in the chapters devoted to the special plates of the Mesabi iron range in this county, and these chapters should be consulted for special descriptions of the area comprised in these plates, which are, beginning at the west, the Akeley Lake, Gunflint Lake, Rove Lake, Mountain Lake and Pigeon Point plates. The description of these is comprised in chapters xxiv to xxviii. The author's detailed acquaintance with this county is largely confined to its northwestern quarter, but he has visited other parts of the county.

†*Fin. Report*, vol. i, p. 114.

divide passes southward a short distance east of the centre of T. 65-2 W., then westward and southwestward to near the southwest corner of T. 64-3 W., then it continues southwestward to near the centre of T. 63-4 W. and westward through T. 63 W. The drainage of the Hudson Bay basin follows two lines in this county, both of which unite in Saganaga lake. The first carries the waters of North, Gunflint and adjacent lakes, and the waters brought from the south by Cross river, and forms the international boundary from Gunflint to Saganaga lake. Along this stream, which, like many others in this part of the state, is a series of lakes connected by short stretches of rapid water, are a number of rapids and waterfalls. One of these falls, over granite, is at the entrance of this stream into Saganaga lake and is shown in figure 2 of plate PP in the chapter on the Pigeon Point plate. The second line of drainage includes Little Saganaga and Gabimichigama lakes, whose waters pass westward into Ogishke Muncie lake in Lake county, and then eastward into Cook county through Frog rock, West Sea Gull and Sea Gull lakes to Saganaga lake.

The streams of the gulf of St. Lawrence drainage all empty into lake Superior. With the exception of the Pigeon river and parts of the Brulé and Devil Track rivers, these streams pursue a course a little east of south, while the three rivers mentioned have a more easterly course. The lower parts of the streams flowing into lake Superior are very rapid and contain many waterfalls. The finest of these is the Pigeon River falls, which is illustrated in the chapter on the Pigeon Point plate. The lower part of the upper falls of Cascade river is shown in plate HH, figure 3.

Lakes. Lakes are abundant, especially in the northern half of the county. Along the international boundary, in the area underlain by Animikie strata, the lakes have a marked east and west elongation, coinciding with the strike of the rocks, and to the south in the Keweenawan area a number of the lakes also show elongation in this same direction. Such are Tucker, Winchell, Brulé and Devil Track lakes. Brulé lake (T. 63-3 W.) is of interest from the fact that it has two outlets, one from its east and one from its west end.* These two outlets are of approximately equal volume, and both flow over rock beds. The eastern stream is the Brulé river, which, after an east-southeasterly course of some forty miles, enters lake Superior in T. 62-3 E. The western stream finds its way into the Temperance river, whose mouth is forty-three miles southwest of that of the former stream. The water which flows through the second outlet travels some thirty miles before reaching lake Superior.

Topography. The surface of Cook county is in general rough and hilly, but not mountainous. The hill ranges have a general northeasterly direction in the southern part of the county, conforming to the lake Superior shore, while farther

*C. P. BERKEY, *Twenty-second Annual Report*, pp. 137, 138.
U. S. GRANT, *Amer. Geol.*, vol. xix, pp. 407-111.

FIG. 1. TRAP ISLAND UNDERCUT BY WAVE ACTION, NORTH SHORE OF LAKE SUPERIOR; EAST SIDE OF R. 5 E. (p. 315.)

[From Photograph by Dr. A. H. Elftman.]

FIG. 2. CARLTON PEAK AND TAFTE POSTOFFICE; T. 59-4 W. (p. 315.)

[From Photograph by A. H. Elftman.]

FIG. 3. LOWER PART OF UPPER FALLS OF CASCADE RIVER; SE. ¼ SEC. 12, T. 61-2 W. THE ROCK IS AMYGDALOIDAL DIABASE AND TUFF, DIPPING AT A LOW ANGLE TOWARDS S. 25° E. (pp. 314, 326.)

FIG. 4. GRAND MARAIS BAY, FROM TWO HUNDRED FOOT BLUFF WEST OF THE BAY. (pp. 316, 339.)

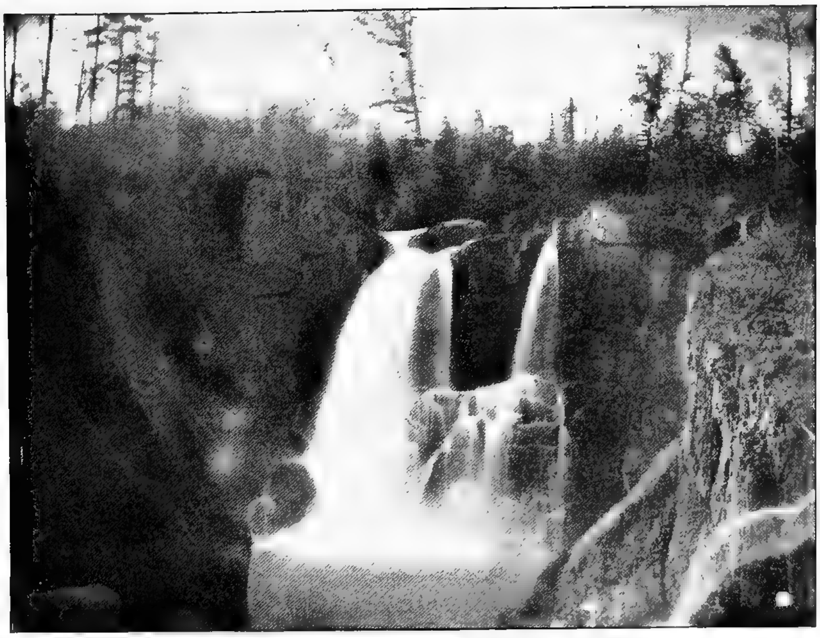
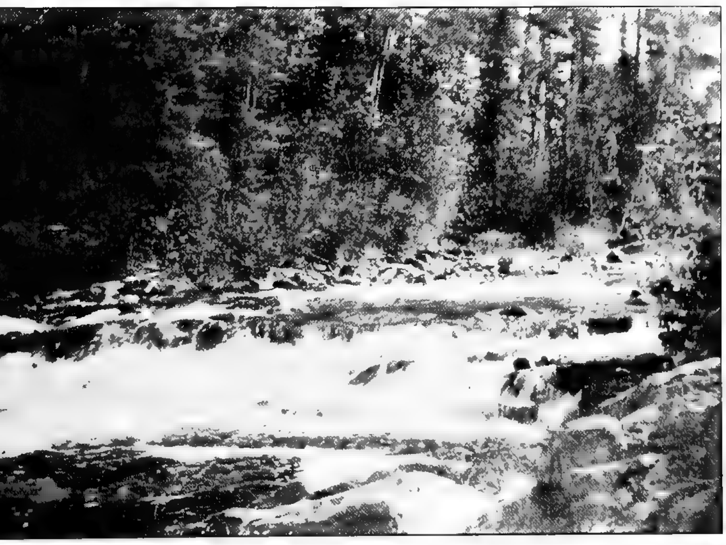


FIG. 1. PIGEON RIVER FALLS, OVER A DIKE CUTTING ANIMIKIE SLATE. (p. 508.)



. 2. BOUNDARY RIVER; SAGANAGA FALLS AT THE ENTRANCE TO SAGANAGA LAKE, OVER GRANITE. (pp. 314, 463.)

FIG. 3 PARTRIDGE FALLS, OVER ANIMIKIE SLATE WHERE HARDENED BY A DIKE THAT CROSSES THE RIVER. (p. 508.)

FIG. 4. GORGE BELOW PIGEON RIVER FALLS; CUTTING ANIMIKIE SLATE. (p. 508.)

FIG. 55. SAWTEETH MOUNTAINS AS SEEN FROM GRAND MARAIS, LOOKING TOWARD THE WEST.
From a sketch by professor N. H. Winchell.

north they run more easterly. Crossing the county from west to east are certain belts which are more or less sharply separated from each other because of differences of topography. From the lake Superior shore the land rises abruptly, and within one to four miles from the shore hill tops are reached which rise several hundred feet above the lake. This marked escarpment is characteristic of the north shore of lake Superior in Minnesota, and the steep slope continues beneath the lake level. Among these hills near the lake are two prominent peaks, mount Josephine and Carlton peak. The former lies at the base of the point which separates Grand Portage and Waswangoning bays and rises 703 feet above lake Superior or 1,305 feet above sea level. Carlton peak (see figure 2 of plate HH) is in sec. 20., T. 59-4 W., and its summit is 927 feet above the lake or 1,529 feet above the sea. The Sawteeth mountains are a prominent feature of the high lands just back from the lake shore; they exhibit markedly serrate tops, as shown in the sketch herewith.

Connected with the lake Superior shore are numerous features of interest. Many of these have been described by Dr. A. C. Lawson,* and from his descriptions much of the following is taken.

There is a very evident relationship between the general topography of the north side of lake Superior and the geological conditions which obtain in different portions of its extent. In Cook county there are two great geological provinces fronting on the lake; these are the Keweenawan and the Animikie. Corresponding to each of these great geological provinces there is a distinct type of topography. And in addition there are three important facts which have controlled the development of the topography of the Minnesota shore of lake Superior. These are: (1) The drainage basin of the lake is a comparatively narrow strip of land. The streams here entering the lake, although rapid, and though actively deepening their trenches, are insignificant in size and bring but a small amount of material to the shore. (2) The rapid deepening of the water off the coast. (3) The exposure of the shore to the open expanse of the lake without the protection of any material breakwaters.

Sea cliffs exist in many places along the lake shore, where it is formed of Keweenawan rocks. These cliffs are seemingly the direct product of shore action and appear to be in active recession. But in cases it would seem that these cliffs are not true sea cliffs, but were developed independent of the lake. In some of the cliffs caves and clefts have been formed by the action of the waves, as well as overhanging cliffs and arched passages. One of the latter is shown in plate HH, figure 1. Here an island, which is composed of part of a nearly horizontal trap-sheet, has had its centre undermined and cut through.

At Good Harbor bay some soft sedimentary shales protected on the lakeward side by a ridge of hard, igneous rock have afforded conditions favorable for shore erosion, and the bay is the result. The cliffs at the back of the bay, being

* *Twentieth Annual Report*, pp. 181-289.

of this soft shale in nearly horizontal attitudes, are actively receding, and a shingle beach has been piled up along the base of the material which has not yet been reduced to clay and carried out to deep water. The beech is not large, and in violent storms is doubtless entirely moved. A few miles farther on Grand Marais harbor presents a fine pebble and shingle beach which extends in the form of a broad based spit connecting the island on which the lighthouse stands with the main shore (see plate HH, figure 4). The material of this beach is again the same red quartz porphyry which has been so often referred to as a source of supply of shore drift. The cliff from which it is in this case derived is a little to the east of Grand Marais.

Fish-hook point, the mouth of Brulé river and Deronda bay are other places where notable beaches occur, and in all these cases they are found in the immediate vicinity of cliffs of red quartz porphyry and the embankments are nearly altogether composed of this material.

These beaches thus briefly alluded to are the only very prominent ones that attract attention in coasting along the shore in Cook county from the west to Grand Portage. The longest of them is probably not more than one-eighth of a mile in length; and if it is borne in mind that these are distributed over a shore of some eighty miles, their mere enumeration is sufficient to indicate the meagerness of beaches along its extent. It is not intended by this explicit allusion to these beaches to imply that there are not others. There are many small coves along the shore, so small that they afford no shelter for a row-boat, and also short stretches of open shore between jutting points, where local detritus has accumulated and has been thrown up into beach form. The proportion of these, however, to the total length of coast is very small. There are also stretches of shore which are essentially bare shelving rock, but which in patches are encumbered with boulders. In general the impression received by inspection of the Keweenian shore from a row-boat is that of a wonderful dearth of shore drift and a great extent of bare rock, and one is constantly struck by the association of the more important beach accumulations with the occurrence of a red quartz porphyry, and an allied and quite similar rock in which quartz cannot be detected macroscopically. This association depends upon the property which this rock has of yielding pebbles by reason of its shattered jointage structure, the resulting fragments being hard and resistant.

In passing from the Keweenian to the Animikie province along the shore of the lake one is impressed by the great contrast which is presented in the relative abundance of beaches. Along the Animikie shore, beaches are the rule except where the great dikes occupy the water's edge. The reason for the difference lies in the diverse petrographical characters of the two formations. In the Keweenian the only rock capable of yielding shore drift in abundance, the red porphyry, is of limited occurrence, and it is prevented from yielding large quantities by its association with harder rocks which keep the line of the shore from receding. In the Animikie province it is far otherwise. The Animikie slates and slaty sandstones and quartzytes occur along the entire Animikie coast and have yielded an overwhelming amount of material eminently suitable for the formation of shingle beaches.

On the shingle beaches storms frequently build terraces or storm beaches a few feet above the present lake level. Plate II, figure 1, shows one of these shingle beaches, at the rear of which are two storm beaches. And figure 2 of the same plate shows other storm beaches and a bar of shingle thrown across the mouth of a stream, whose waters enter the lake by seeping through the shingle.

Pot-holes are not commonly developed on lake shores. They are usually the products of stream action. On one part of the Minnesota shore, however, they are distinctly the product of wave action, and may be observed in process of formation. The place where they were observed is on the shore about two miles east of the mouth of the Temperance river. Here the shore is occupied by an amygdaloidal lava of uneven texture, which forms a shelving, lakeward sloping platform. In this platform are numerous pot-holes, the deepest having a depth of about four feet and a diameter at the mouth of about three feet. In the bottom of the pot, unless it is very shallow or has been breached, there are always one or more hard erratic boulders which do the work of grinding out the hole when set in motion by the waves pouring over the surface of the platform. The holes are not as symmetrical as those formed by stream action, but there is no essential difference between them and the latter. It is to be noted that the rocks which are here susceptible of having pot-holes developed in them by wave action also afford in the canon of the Temperance river the finest, though not the largest, pot-holes to be seen in any of the streams of this coast. The canon of the river is formed by a systematic series of deep pot-holes which have breached into one another, giving the walls of the canon a concavely scalloped form.

In the form of the shore line the two geological provinces (the Keweenawan and the Animikie) differ markedly. The shore line in the Keweenawan province is, on the whole, a remarkably simple line. It has the form of a slack bow concave to the lake. Projecting headlands and deep bays are entirely absent. Such salients and re-entrants as are worthy of note are obtuse in form and do not appreciably add to the length of the shore line. Yet, in minute detail, the line is frequently sharply jagged and serrate, and there is a marked absence of those sweeping sinuous curves which characterize mature shores. Shore erosion is active in the production of coves, and the whole tendency of development appears to be, in this adolescent stage of the shore, the reverse of simplification. The present stage of the lake found the shore without indentations, and a vigorous beginning has been made in the work of evolving them and in effecting a more intricate form of shore contour. But it is scarcely more than a beginning. The notches, clefts and coves of the shore can only be rendered appreciable on a very large scale map, and do not affect the general statement of the simplicity of the shore line considered as a whole.

The general trend of the shore along the front of the Animikie province is not a simple line. Deep, narrow bays, and prominent, sharp headlands prevail, and the length of shore line is large in proportion to the extent of

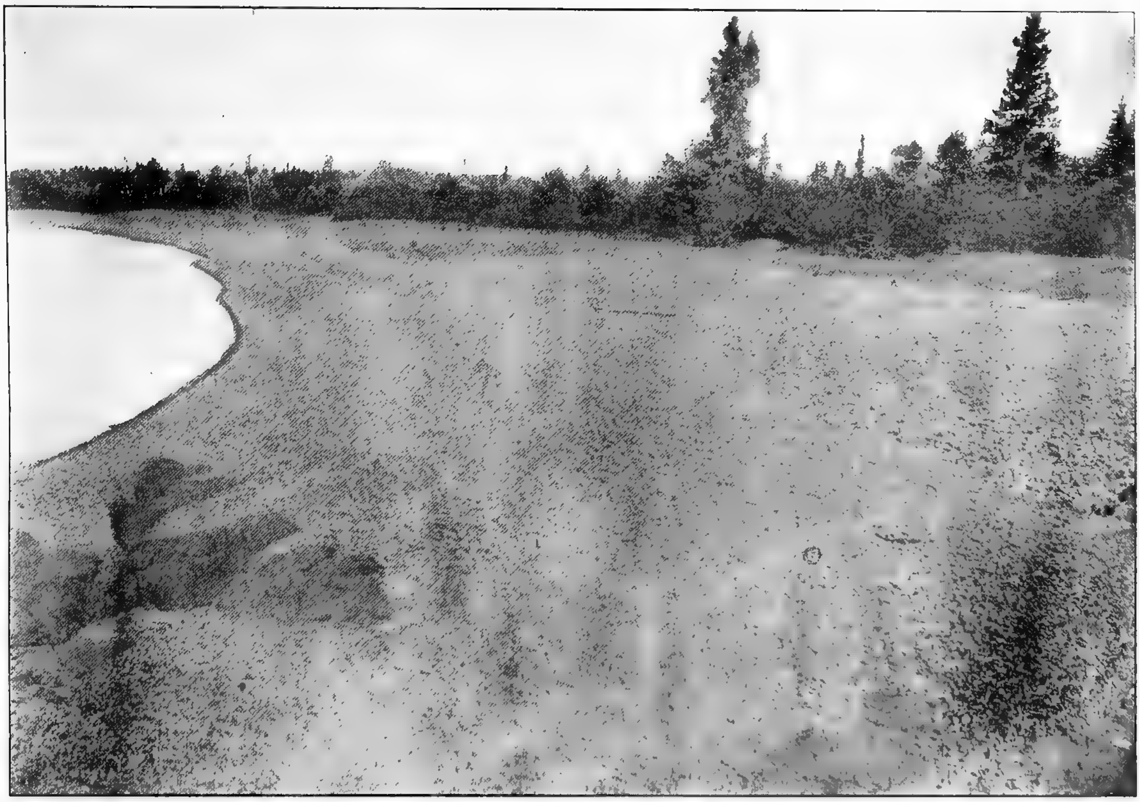


FIG. 1. SHINGLE BEACH AT THE REAR OF WHICH ARE TWO STORM BEACHES, MOUTH OF BRULE RIVER, NORTH SHORE OF LAKE SUPERIOR. (pp. 316, 333.)

FIG. 2. SHINGLE THROWN ACROSS THE MOUTH OF REDROCK RIVER, AND STORM BEACHES, NORTH SHORE OF LAKE SUPERIOR. (p. 316, 328.)

the coast. The sculpture which gave rise to these bays and points is pre-lacustrine, and the tendency of the shore action is, in contrast to that noted on the shore of the Keweenawan province, towards simplification. The tendency in this direction is, however, not strongly marked on account of the resistant character of the extremities of the promontories, which have not yet been appreciably truncated at the line of the present stage of the lake. The tendency is chiefly manifest in the filling up of the heads of the bays. While the shore contour of the Animikie province is in strong contrast to that of the Keweenawan by reason of these large salients and re-entrants, there is also a radical difference in the minute detail of the shore contour in the intervals between the points and along those portions of the shore which are exempt from bays. There is very little of the sharp, local notching and clefting of the shore line where the shore is rocky, and none of it where the shore is occupied by shingle. Thus the shore contour of the Animikie province is intricate in its general features, but simple in its minute detail, while that of the Keweenawan is simple in its general features and serrate in its minute detail. The conditions governing the local trend of the bays and points along the Animikie front is easily recognizable, and there is a prevailing parallelism in these features.*

Beyond, to the north of the sudden rise in the land near the lake shore, is a surface which is still rough, but has no very marked elevations. This district includes a tract of land extending from the top of the hills, which rise so suddenly from the lake, northward, for several miles. The north limit of this district may be taken as a line running from the Pigeon river a few miles south of South Fowl lake southwestward to near Elephant lake, and thence a little south of west to the western edge of the county.

Farther north, described in the chapters devoted to the Gunflint Lake and Rove Lake plates, is a belt, from six to ten miles in width, extending from the western side of the county eastward beyond the Grand Marais and Rove Lake road. Here are several east and west hill ranges, made, for the most part, of Keweenawan granites. One of these ranges (the Misquah hills), which lies near the south side of Ts. 64–1 W. and 64–2 W., contains points over 2,200 feet above sea level, or 1,600 feet above lake Superior. One point, in the Misquah hills, south of the east end of Winchell lake, in sec. 36, T. 64–2 W., is 2,230 feet above the sea, and is the highest point known in the state. Two other prominent points are Brulé mountain, south of the Brulé river, in sec. 21, T. 63–1 W., which is 2,170 feet above the sea; and Eagle mountain, near the southern edge of T. 63–2 W., whose hight has not been determined.

To the north of these hill ranges is a less rough district, which is underlain by gabbro. In places this is quite hilly, but again it becomes comparatively flat, as in the northern half of T. 64-2 W. The characters of this district are described in the chapters devoted to the special plates, especially in those referring to the Gunflint Lake and Fraser Lake plates.

Still to the north, and forming the northern border of the county from the west side of Gunflint lake to Pigeon point, is another district, of topography quite distinct from any of the others above mentioned. In fact, it is the only district which is very markedly everywhere distinct from the others. This is the district underlain by Animikie rocks. Here there are parallel east and west ridges, capped by diabase sills; the northern slope of each ridge is steep and frequently precipitous, while the

* Other features of the lake Superior shore, *i. e.*, the abandoned beaches, are described further on in this chapter.

southern slope is quite gentle. Towards the east, in the vicinity of Pigeon point, the hill ranges, which follow the same general direction, are steep on both sides, being formed by great vertical diabase dikes instead of southward dipping diabase sills.*

The Archean area, which forms the northwestern corner of the county, has, at the south (Ts. 65–4 and 65–5 W.), a massive, east and west hill range (the Giant's range) formed of granite on the east and of greenstone on the west. This range rises in places to a hight of 2,000 feet above sea level. On the north the Giant's range slopes toward Saganaga lake, and this lake lies in a comparatively flat district underlain by the same granite which forms the eastern part of the Giant's range in this county.

Elevations. The elevations of the following points have been determined. Other elevations may be found by consulting the chapters and maps devoted to special areas in this county—chapters xxiv to xxviii, plates 81 to 85.

Elevations determined by leveling.†

	Feet above the sea.
Lake Superior (datum),	601.56
Devil Track lake, T. 62–1 west,	1,636
Little Pine lake, sec. 35, T. 63–1 west	1,837
Club Foot lake, sec. 34, T. 63–1 west,	1,885
Round lake, sec. 34, T. 63–1 west,	1,920
Lake Abita, sec. 21, T. 63–1 west,	2,048
Brulé mountain, sec. 21, T. 63–1 west,	2,170
Brulé River lakes, sec. 16, T. 63–1 west,	1,649
Little Trout lake, sec. 5, T. 63–1 west,	1,910
Ridge south of this lake,	1,994
Misquah lake, sec. 32, T. 64–1 west,	1,911
Hill east of this lake (one of the Misquah hills)	2,223
Cross lake, sec. 29, T. 64–1 west,	1,866
North Brulé lake, sec. 19, T. 64–1 west,	1,854
Gaskanas lake, sec. 26, T. 64–2 west,	1,874
Winchell lake, secs. 26 to 30, T. 64–2 west,	1,910
Hill south of this lake, in sec. 34, T. 64–2 west,	2,213
Sham lake, sec. 36, T. 64–3 west,	1,915
Brulé lake, secs. 13 to 18, T. 63–3 west,	1,851
Hill at west end of Brulé lake, sec. 18, T. 63–3 west,	2,084
Georgia lake, sec. 13, T. 63–4 west,	1,841
Surveyors' lake, sec. 12, T. 63–4 west,	1,849
Lake Ida Belle, sec. 2, T. 63–4 west,	1,794
Narrow lake, sec. 35, T. 64–4 west,	1,782
Kiskadinna lake, sec. 24, T. 64–4 west,	1,767
Ham lake, sec. 35, T. 65–4 west,	1,706
North quarter post, sec. 28, T. 65–4 west,	2,038
Loon lake, secs. 32 to 36, T. 65–3 west,	1,745
Mayhew lake, sec. 36, T. 65–3 west,	1,853
Beaver lake, sec. 33, T. 65–2 west,	1,880
Tucker lake, secs. 2 to 4, T. 64–3 west,	1,847
Banadad lake, secs. 10 to 12, T. 64–3 west,	1,944
Lake, secs. 7 and 8, T. 64–2 west,	1,942
Lake, sec. 10, T. 64–2 west,	1,927
Poplar lake, sec. 7, T. 64–1 west,	1,859
Straight lake, secs. 7 and 18, T. 64–1 west,	1,879
Caribou lake, sec. 18, T. 64–1 west,	1,868

*See the chapters on the Gunflint Lake and Pigeon Point plates for descriptions of the topography peculiar to the Animikie. Also, see figures 2-4 of plate NN, in the chapter on the Gunflint Lake plate.

†The leveling was done in 1893 by Messrs. L. A. Ogaard and A. N. Winchell.

	Feet above the sea.
Meeds lake, secs. 14 and 15, T. 64–2 west,	1,879
Hungry Jack lake, secs. 2 to 4, T. 64–1 west,	1,687
Birch lake, secs. 33 to 36, T. 65–1 west,	1,684
Daniels lake, sec. 25, T. 65–1 west,	1,684
Duncan's lake, sec. 28, T. 65–1 west,	1,664
Rose lake, secs. 20 to 24, T. 65–1 west,	1,528
Rat lake, sec. 19, T. 65–1 west,	1,531
South lake, secs. 22 to 24, T. 65–2 west,	1,558
North lake, sec. 15, T. 65–2 west,	1,550
Gunflint lake, secs. 19 to 24, T. 65–3 west,	1,547
Chub (Akeley) lake, sec. 29, T. 65–4 west,	1,779
Paulson lake, sec. 25, T. 65–5 west,	1,708
Kakigo (Black Trout) lake, sec. 34, T. 65–5 west,	1,663
Bashitanaqueb lake, sec. 2, T. 64–5 west,	1,657
Clothespin (Peter) lake, secs. 32 to 34, T. 65–5 west,	1,608
Gabimichigama lake, sec. 31, T. 65–5 west,	1,587
Agamok lake, sec. 31, T. 65–5 west,	1,585
Little Saganaga lake, secs. 7 to 9, T. 64–5 west,	1,600
Muscovado lake, sec. 36, T. 65–5 west,	1,706
Green lake, first east of last,	1,730
Charley lake, sec. 32, T. 65–4 west,	1,763
Gaiter lake, just northwest of last,	1,782
Bear lake, secs. 33 and 34, T. 65–4 west,	1,748
Flying Cloud lake, north part sec. 31, T. 65–4 west,	1,738
Greenwood Island lake, sec. 11, T. 64–5 west,	1,641
East and West lake, secs. 14 and 15, T. 64–5 west,	1,618
Mount Josephine, northeast of Grand Portage bay,*	1,305
Carlton peak, sec. 20, T. 59–4 west,*	1,529
Pike lake, secs. 15 to 17, T. 61–2 west†,	1,482

Elevations less accurately determined.

	Feet above the sea.
South Devil Track lake, sec. 31, T. 62–1 east,	1,613
Hill south of Little Pine lake, sec. 35, T. 63–1 west,	1,995
Hill three miles east of Brulé mountain, sec. 24, T. 63–1 west,	2,050
Hill northeast of Little Trout lake, sec. 5, T. 63–1 west,	2,023
Hill near Winchell lake, sec. 36, T. 64–2 west,	2,230
Ridge south of Brulé river, sec. 22, T. 63–2 west,	2,027
Granite ridge, sec. 14, T. 65–4 west,	1,967
Ridge in sec. 23, T. 65–4 west,	1,942
Sea Gull lake, secs. 9 to 12, T. 65–5 west,	1,440
Ridge south of Gunflint lake, sec. 25, T. 65–4 west,	1,892
No-name lake, secs. 34 to 36, T. 65–2 west,	1,787
Portage lake, secs. 3 to 5, T. 64–2 west,	1,872
Hill south of Hungry Jack lake, sec. 3, T. 64–1 west,	1,902
Hill south of Duncan's lake, sec. 4, T. 65–1 west,	1,907
Rose Lake mountain, secs. 20 and 21, T. 65–1 west,	1,997
Hill in sec. 31, T. 65–5 west,	1,827
Hill in sec. 29, T. 65–5 west,	1,867
Little Round lake, sec. 12, T. 64–5 west,	1,677
Big Round lake, secs. 7 and 8, T. 64–4 west,	1,702
Little Copper lake, secs. 9 and 10, T. 64–4 west,	1,777
Lake in sec. 15, T. 64–4 west,	1,867
Hill, one-fourth mile west of this lake,	1,967
Snipe lake, sec. 3, T. 64–4 west,	1,757
Hill north of this lake,	1,927
South Fowl lake, sec. 1, T. 64–3 east,	1,436
North Fowl lake, sec. 26, T. 65–3 east,	1.440
Moose lake, secs. 19 to 21, T. 65–3 east,	1,492
Mountain lake, secs. 14 to 18, T. 65–2 east,	1,652
Rove lake, secs. 19 to 22, T. 65–1 east,	1,667
Pine lake, secs. 1 and 2, T. 65–4 west,	1,465

*As determined by the U. S. Lake Survey.
† As determined by Dr. A. H. Elftman.

	Feet above the sea.
Granite (Banks Pine) lake, secs. 10 and 15, T. 66-4 west,	1,448
Saganaga lake, northeast edge of Cook county,	1,434
Red Rock lake, secs. 28 and 33, T. 66-5 west,	1,435
West Sea Gull lake, sec. 8, T. 65-5 west,	1,450
Sea Gull lake, secs. 9 to 12, T. 65-5 west,	1,440
Frog Rock lake, sec. 18, T. 65-5 west,	1,470

The highest known point in Cook county, and in the state of Minnesota, is the hill already mentioned (page 317), which rises 2,230 feet above the sea. The lowest water surface is lake Superior, 602 feet. This makes a difference of 1,628 feet between the extremes of altitude in Cook county. Mr. Warren Upham has estimated the mean altitude of the county as 1,550 feet above sea level.

Soil and timber. Wherever there is sufficient soil for farming, and such areas are common throughout the county, but more especially in the drift covered country just back of the steep hills which rise from lake Superior, crops can be raised in abundance; in fact, most of the common farm products, except, perhaps, Indian corn, can be grown. Farming has been carried on in several places along the lake shore, as at Poplar river (Lutsen) and Grand Marais. Back from Grand Marais, in the vicinity of Devil Track lake, is good farming country, and large parts of the Pigeon River Indian reservation are well adapted to agriculture. As the country is developed more and becomes better settled, it will be found that large tracts can be farmed.

The county is timbered and much white and Norway pine is present, little lumbering having as yet been done. Birch and sugar maple are also common, the latter being especially abundant in the western part of the Pigeon River Indian reservation. And poplar and spruce are abundant.

GEOLOGICAL STRUCTURE.

Within the area of Cook county there are the following geological formations, the most recent being placed at the top:

Post-glacial,
Glacial,
Keweenawan,
Animikie,
Archean.

The three which lie below the glacial deposits may be briefly described as follows: At the northwest corner of the county is an area of Archean rocks consisting of granites, greenstones, conglomerates, slates, schists, etc. These are the oldest rocks in the county. They have been much folded and eroded, and on their worn surfaces the Animikie strata were deposited. Rocks of the latter age lie to the south of the Archean area and dip towards the south, usually at a low angle. South of the Animikie strata and in general overlying them are the Keweenawan rocks, which are in part (Cabotian) igneous rocks composed largely of gabbro and granite. South

of the Cabotian rocks and overlying them and dipping to the south under lake Superior are other Keweenawan rocks, which consist of conglomerate and sandstone and large amounts of igneous material (Manitou), much of which is in the form of surface flows.

The Archean. The Archean rocks are confined to a comparatively small area at the northwestern corner of the county, and they are conveniently divided into four groups—greenstones, Lower Keewatin, granite and Upper Keewatin. The greenstones are composed essentially of aggregates of hornblende and a plagioclase feldspar, and they are regarded as originally basic igneous rocks which are now more or less altered and may be called diorytes. As stated in the chapter on the Akeley Lake plate, there are some reasons for regarding some of the greenstones as the oldest rocks in the county, even more ancient than the Lower Keewatin rocks, but that they are thus of pre-Keewatin (Archean, as that term is used by the U. S. Geological Survey) age is not certain. These greenstones are well exposed all through the area mapped as underlain by them, but they can most conveniently be seen at Frog Rock lake, at the southern end of West Sea Gull lake and along the northern border of the Animikie rocks as far east as sec. 27, T. 65-4 W. The greenstones are cut by a few quartz porphyry and quartzless porphyry dikes.

The Keewatin rocks consist of greenstones, green schists, sericitic schists, argillytes, graywackes, jaspilytes, conglomerates, etc. It is possible to divide the Keewatin into two series separated by a marked unconformity. Unfortunately, our present knowledge will not enable us to everywhere separate these two parts of the Keewatin, so we have been compelled to map some territory as underlain by Keewatin which has not been separated into the two parts. Older than the Upper Keewatin, and belonging, in part at least, to the Lower Keewatin, are granite, jaspilyte, greenstone and flinty slate, all of which occur as pebbles in the basal conglomerate of the Upper Keewatin. With this later series, we know, belong some conglomerates, argillytes and graywackes, and in part we are able to outline the area underlain by these later rocks. The Upper Keewatin is unconformable on the Lower Keewatin, but contacts between the two have not been reported in this county. However, contacts between the basal member of the Upper Keewatin and the granite and greenstone are known. At such places the later rocks are found resting unconformably on the older. One of the best places to see this unconformable overlie is near the west shore of West Sea Gull lake, and another is at the extreme northwestern corner of the plate at Saganaga lake.

At the latter place a junction between the granite and the Keewatin clastics has been known for some years, but it seems in general to have been taken for an eruptive contact, and the writer thus described it.* Later, opportunity was had to

* *Twentieth Annual Report*, pp. 83-95; *Amer. Geol.*, vol. x, pp. 4-10.

study thin sections of the rocks collected at this locality, and it then became evident that the rock which had been regarded as a contact facies of the granite was in reality a clastic rock composed of granitic debris little assorted. This, when consolidated, makes a recomposed granite. At once the conclusion was reached that here was an unconformable overlie of Keewatin clastics on granite. A visit to this spot in September, 1896, in company with Messrs. N. H. Winchell, A. H. Elftman and H. F. Bain showed that the conclusion reached from a study of the rock sections was correct. At the actual contact between the two rocks it is quite difficult to tell them apart; about the only difference observable macroscopically is that in the recomposed granite (base of the Upper Keewatin) the hornblende of the true granite is lacking. On going farther away (west) from the granite, the recomposed granite becomes similar to and grades into graywackes interbedded with slates. The slates and graywackes are well exposed in the little bay of Saganaga lake in sec. 24, T. 65-6 W., and on going overland between this bay and the adjacent bay in sec. 19, T. 65-5 W., the actual contact between the granite and the recomposed granite can be found. At the portage to Oak lake at the west end of Saganaga lake, and for a quarter of a mile or more east of this portage, on both sides of the international boundary, the recomposed granite is well exposed. Rock samples (2031 to 2045) were collected at this locality and represent different phases of the recomposed granite; they will be described in the chapter devoted to petrography.

The Archean granite which is found in Cook county is confined to the vicinity of Saganaga lake and the district between this lake and Gunflint lake. It is a coarse-grained gray to reddish granite and is known as the *Saganaga granite*. The chief components are quartz, orthoclase, acid plagioclase and hornblende; the rock is thus a hornblende granite, and typical samples of it are numbered No. 686G. A peculiar and characteristic feature of this granite is its large grains of quartz, which are conspicuous on weathered surfaces. The quartzes are commonly a quarter of an inch in diameter, and they frequently become larger. While the granite mass is as a whole quite uniform in composition and grain, it varies in places, especially along its southern border in T. 65-5 W., to a more basic rock. The quartz becomes scarcer and is sometimes practically lacking, and the rock becomes a hornblende syenyte. At the same time the lime-soda feldspar, which is present to a considerable amount everywhere, as far as examined, increases in quantity as the quartz decreases, and the rock varies not only to a syenyte, but also to a dioryte. Sphene (titanite) is a common constituent of the granite, and in places the sphene crystals become quite noticeable macroscopically (686G).

On an island in Saganaga lake (S. E. $\frac{1}{4}$ N. W. $\frac{1}{4}$ sec. 14, T. 66-5 W.) is a large white quartz vein in which a number of years ago some mining for gold and silver

was carried on, but without success. The main rock of this island is a fluorite granite (Nos. 676G, 677G, 678G, 2046), and this, as far as the writer knows, is the only fluorite granite reported from the state. The fluorspar is not in great amount, but is scattered in small grains throughout the rock.

The Saganaga granite is cut by a few small dikes of a much finer grained granite, or aplyte, which is composed almost entirely of quartz and alkali feldspar. Samples from one of these aplyte dikes are Nos. 681G and 682G.

The relations of the Saganaga granite to the Upper Keewatin have already been spoken of. Its relations to the greenstones are entirely different in a number of places, the most conspicuous of which are (1) The bluff on the south shore of West Sea Gull lake, in N. W. ¼ N. E. ¼ sec. 17, T. 65–5 W., and (2) A locality just west of this lake in the S. E. ¼ sec. 7, T. 65–5 W. At both localities the granite is seen cutting the greenstone in a complex of branching vein-like forms, but the second locality shows these branching tongues of the granite to the best effect. At the first locality, however, the relations of the two rocks are sufficiently distinct.

The relations of the granite to the Lower Keewatin rocks are not definitely known. As has already been stated, the Saganaga granite is older than the Upper Keewatin and younger than the greenstones along its southern border, but the relations of this mass of granite to the Lower Keewatin rocks have not been observed in this county, unless these greenstones be of Lower Keewatin age. Dr. A. C. Lawson has described a conglomerate cut by the Saganaga granite near the northwest corner of Saganaga lake, in Canadian territory,* and Dr. A. H. Elftman informs the writer that he has observed this same granite cutting a conglomerate and other clastics farther towards the east. It would thus seem that the Saganaga granite is younger than the Lower Keewatin.

The Animikie. The Animikie rocks rest unconformably on the granite, the greenstones and some of the Keewatin rocks. Animikie strata occur in a small area on the south side of Gabimichigama lake at the west line of the county. They next appear about four miles farther northeast (in N. W. ¼ sec. 34, T. 65–5 W.) and then continue uninterruptedly to the extreme eastern side of the county at Pigeon point. At first (on the west) the belt occupied by these rocks is very narrow, but towards the east it soon widens out and spreads both north and south of the international boundary.

The northern limit of the Animikie lies along the southern side of the Giant's range and the strata dip off gently to the south, or a little east of south. Towards the east the dip is small, and at times is almost flat, but in general the angle of dip is from 8° to 10°. Towards the west the angle of dip increases, and in some places

* *Amer. Geol.*, vol. vii, p. 324, May, 1891.

reaches 50° to 60°, or even higher. The Animikie strata thus form a gentle southward dipping monocline. In some places, especially west of Gunflint lake, the simple monoclinal structure is replaced by some small folds in the taconyte or iron-bearing member. The axes of these folds run approximately east and west, and the most noticeable fold is a syncline in the southern parts of secs. 21 and 22, T. 65-4 W.

In Minnesota the Animikie has been divided into four members,* which, in descending order, are as follows:

Graywacke-slate member.
Black slate member.
Taconyte or iron-bearing member.
Quartzyte member (Pokegama quartzyte).

The lower two are typically developed in St. Louis county, where the black slate, and also perhaps the upper member, is known. In Cook county all but the lowest member are typically developed, and this lowest member is lacking. No fragmental quarzyte, except a few small layers in the taconyte member, is known at the base of the Animikie in Cook county.

The Taconyte or iron-bearing member shows the usual features of this member as already described in St. Louis county.† The rocks of this member are confined to a belt some nine miles in length extending westward from Gunflint lake, and to a small area between this lake and North lake. A considerable part of Gunflint lake is undoubtedly underlain by these rocks, which pass entirely into Canadian territory at North lake.

To the south of the taconyte member is the overlying black slate member which is composed largely of black carbonaceous slates, often very fissile, but sometimes quite massive in appearance. Some of the more massive parts of this member are well exposed near the top of the bluff, at the first rapids above the mouth of Cross river, which flows into the west end of Gunflint lake (No. 961G to No. 961cG). This member is found in outcrop near the south shores of Gunflint, South and Rose lakes, and, as far as known, it passes entirely into Canadian territory before reaching Rove lake.

The graywacke slate or upper member of the Animikie forms the main mass of the rocks of this age in Cook county. On the west it first appears west from Loon lake and continues eastward to and beyond the limits of the county. This member is composed of black and gray siliceous slates, graywacke slates, and fine quartzytes and quartz slates. The quartzyte layers are seen in places along the south side of Loon lake, near the top of the Animikie as there exposed, and on going eastward the quartzyte and quartz slate increase in amount and form the main mass of the upper member of the Animikie. These quartzytes are well known

* *Twenty-second Annual Report*, p. 74.

† See *Twentieth Annual Report*, pp. 111-180; *Bulletin 10;* and the chapters on the northern part of St. Louis county, and on the special plates of the Mesabi iron range in that county in this volume.

in the vicinity of Pigeon point, where the name Wauswaugoning quartzyte has been applied to them; they are described in the chapter on the Pigeon Point plate. In the vicinity of the Puckwunge river, south of South Fowl lake, and especially along the Grand Portage trail there is a fine-grained graywacke-like rock which Prof. N. H. Winchell has named the Grand Portage graywacke, and referred to the upper part of the Animikie above the clastics of Pigeon point.*

The Animikie strata have been intruded by vast amounts of igneous matter which has solidified in the form of diabase. This igneous material takes two forms—sills, parallel to the strata, and dikes which cut the strata in various directions. The dikes are usually vertical and commonly run approximately east and west. The sills and dikes vary in thickness from a few inches to a hundred feet or more. On account of the more resistant nature of these igneous rocks they stand up above the general level of the Animikie strata and form a large part of the outcrops. From these numerous outcrops, especially of the sills, one might reach the conclusion that a much greater thickness of these rocks exists than is actually the case. To these sills are due the sharp, northward facing cliffs which are so characteristic of the region of the international boundary in Cook County.†

The Keweenawan. Lying to the south of the Animikie area and extending to the lake Superior shore are the Keweenawan rocks. These dip southward or south-southeast at low angles, and underlie three-fourths or more of the county. The vast mass of these rocks is of igneous origin, and only comparatively few sedimentary beds are known. The Keweenawan rocks have been divided by the state geologist into three parts, which, in descending order, are as follows:

Igneous rocks, Manitou.
Conglomerate and sandstone, Puckwunge.
Igneous rocks, Cabotian.

The conglomerate is regarded as forming the base of an unconformity which separates the Keweenawan into two divisions. Associated with the Manitou rocks are some red sandstones which are of later date than the conglomerate, but which can be conveniently classed with it, the conglomerate, sandstones and Manitou igneous rocks forming the upper division of the Keweenawan.‡

(1). The Cabotian. In this division, the oldest of the Keweenawan, are included three general classes of rocks: (1) Gabbro; (2) Granite and its finer grained equivalents; (3) Diabase and other basic surface and dike rocks.

The gabbro—the great gabbro mass of northeastern Minnesota—occupies a considerable tract of country to the south of the Animikie. This rock mass consists of

*See the description of the Pigeon Point plate.

†For a description of the dikes in the Animikie see the chapter on the Pigeon Point plate, and for an account of the sills see the chapter on the Gunflint Lake plate and also *Bulletin* 8, pp. 24-48.

‡These upper and lower divisions of the Keweenawan do not agree fully with the Upper and Lower Keweenawan, as described by R. D. IRVING, *U. S. Geol. Survey, Mon. 5.* The divisions of the Keweenawan, as used in this report, are discussed in the chapter on structural geology, in vol. v.

a coarse-grained granitic aggregate of plagioclase (usually near labradorite), augite (diallage), olivine and magnetite (titaniferous); sometimes an orthorhombic pyroxene is present. The rock varies at times on account of the greater or less amount of the constituent minerals. The two most noticeable variations, as exhibited in Cook county, are towards a pure plagioclase rock (anorthosyte) and towards a titaniferous magnetite. The first is seen in the vicinity of Little Saganaga lake, T. 64–5 W., and the second occurs at several places, as at Mayhew lake, just north of Tucker lake, and west of Brulé lake, in secs. 21 and 22, T. 63–4 W. On the east the gabbro is found in contact with the upper or graywacke-slate member of the Animikie, and in going west the gabbro comes in contact with lower strata, successively lying on the black slate member of the Animikie, the iron-bearing member of the Animikie, and the Archean clastics and greenstones, while still further west (in Lake county) it lies on Archean granite. The gabbro has exercised a marked influence on the rocks with which it has come in contact, at the contact the older rock being completely recrystallized. This metamorphism can be seen in a number of places at the northern edge of the gabbro, but is especially well marked at the southwest corner of Loon lake, where the rocks of the upper member of the Animikie are recrystallized, and westward from sec. 27, T. 65–4 W., where the iron-bearing member of the Animikie has been profoundly affected. The characters of the gabbro mass seem to indicate that it was in the nature of a great laccolith, but the southern or upper side of this mass has not been studied sufficiently to clearly demonstrate the laccolitic nature of the gabbro.

Granites exist in a number of places in or to the south of the gabbro area. They usually form belts trending west-southwest and east-northeast, and, on account of their resistant nature, commonly make hill ranges. The granites in places reach the lake Superior shore, but in general along this shore these rocks are represented by finer-grained facies, such as quartz porphyries. In general the granites are of later date than the gabbro, and dikes of the former cut the latter, as at lake Ida Belle in the northeastern part of T. 63–4 W. The granites are usually of rather fine grain and are red in color. The constituent minerals are mainly feldspar (orthoclase, anorthoclase, acid plagioclase), quartz, hornblende and augite.

Diabase and other surface and dike rocks of the Cabotian are common. They occupy in general a belt of country south of the gabbro and granites and frequently extend to the lake Superior shore. Such rocks are also found much farther north, as in the vicinity of Brulé lake. The surface flows are frequently amygdaloid and closely resemble the later flows of the Manitou (see figure 3 of plate HH, where the Cascade river is shown descending over layers of coarse and fine-grained amygdaloidal diabase and tuff; these layers dip at a low angle towards S. 25° E.; S. E. ¼

sec. 12, T. 61–2 W.) One of the most persistent belts of Cabotian rocks is that known as the Beaver bay diabase which is found at or near the lake shore for considerable distances both east and west of Beaver bay. This rock in its typical form is a coarse-grained, almost black, olivine diabase. It forms in places a marked range of hills (the Sawteeth range) a short distance north of the lake shore (see figure 55 on page 315). In places, as at Carlton peak (see figure 2 of plate HH), this diabase includes vast masses of coarse-grained anorthosytes, which have been described by Drs. A. C. Lawson* and A. H. Elftman.†

(2). Puckwunge conglomerate. The basal rock of the upper part of the Keweenawan is a conglomerate which grades upward into a sandstone. This conglomerate and sandstone are known in several places, as on the north side of Grand Portage island, or a short distance west of Grand Portage, and north of Otter lake in T. 64–3 E. These occurrences are described in the chapters on the Pigeon Point and Mountain Lake plates. Along the lake Superior shore in some places there are beds of red sandstone mixed with more or less igneous material. Such occur at the mouth of Poplar river (Lutsen) and at Good Harbor bay.

(3). The Manitou. This consists of igneous rocks, which are mainly basic, and which occur most commonly as flows. These rocks are, in general, confined to a narrow belt along the lake Superior shore. These flows are at times cut by diabase dikes, also of Manitou date. In this connection it should be mentioned that dikes of comparatively unaltered diabase are found cutting all of the different formations in Cook county, but (1) as there evidently were two or more dates for the intrusion of these dikes, and (2) as the dikes are so uniform in lithological character, it has been impossible to state the age of all of these dikes, except to say that they are referred to the Keweenawan.

The lake Superior shore. Starting on the west and going northeastward along this shore numerous outcrops are seen, notes upon which are as follows.‡ In connection with these notes reference should be had to plates FF and GG, especially the latter, in the chapter on Lake county.§

No. 161. Diabase from the shore at the town line between ranges 5 and 6 (on section 36), one of the layers associated with altered conglomerate in an amygdaloidal state, some having thalite and mesolite. Some has what appears like prehnite (lintonite?) and some calcite. These are not evenly disseminated, but often are found in patches or clumps closely aggregated, the rest of the rock having less.

No. 161A. Brown, aluminous vein-rock in No. 161. These veins are from two to four inches wide and contain heulandite.

No. 161B. Pebbles of mesolite, from the top of No. 161.

No. 162. Amygdaloid, from the same place as No. 161.

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* *Bulletin 8*, pp. 1–23.

† *Twenty-second Annual Report*, pp. 174 179; also in unpublished manuscript.
The anorthosytes at Carlton peak are to be discussed by N. H. WINCHELL in the chapter on structural geology in vol. v of this report, and by A. H. ELFTMAN in the *American Geologist*.

‡ Taken from the notes of N. H. WINCHELL, *Ninth Annual Report*, pp. 42 61.

§ The rocks here mentioned are described in detail in vol. v.

From the last place to Sugar Loaf point the coast is low, with much stony and gravelly beach, the points only being of rock. This rock is coarse dark trap.

No. 163. From Sugar Loaf point –a small point enclosing a little bay and harbor on the northwest side with a sandy beach, and having a conspicuous tuft of trees standing isolated from the low shore lying next west of it. The rock is rough trap, consisting of two sorts, and dipping S. 10° E., at an angle of about 12°. The upper part appears to be somewhat more uniform and basaltic, or massive, and of a greenish color, eighteen feet thick. The lower is harder and has many concretions and amygdaloidal spots. These spots are in nests, the amygdules being of mesolite and stilbite (?). There are, perhaps, of this, three or four feet, but it is irregularly bedded, and contains pebbles as if conglomeratic. These pebbles and enclosed masses seem to be so thoroughly embraced in the rock that they were more likely to have been in the molten mass—semi-fused—than to have been of marine origin. The greenish color of the upper portion seems to come from the weathering of the firm trap. The upper portion also becomes globuliferous in disintegrating under the weather, exhibiting the characters that have been ascribed to melaphyre.

East of Sugar Loaf point, to Two islands, the coast is rocky most of the way, particularly in the western portions, with several short pebbly beaches. The rock is of the same sort as at the point, and along the beach are strewn white pebbles of mesolite, with stilbite. The coarse basalt of the point rises again immediately on the east of the bay, disclosing purgatories below it in the amygdaloid, the bluff rising twenty-five feet, and being cut by canyon-like gorges, and crossed by two or three little streams before reaching Two Island river.

No. 164. Trap rock, like No. 163, dipping toward the lake at an angle of about 12°, between Sugar Loaf point and Two Island river.

No. 165. From the westerly of the Two islands the rock rises about forty feet, basaltiform on the west side dipping southeast, conformably with the dip of the rock on the shore. The westerly is the larger island, forty rods long, the other being about twenty feet high and twenty rods long. The rock is similar to that of No. 163.

The Two Island river, like many others, is closed during the summer months by a gravely spit that turns westerly from its point of starting from the shore, under the action of the wind and waves of the lake as opposed by the current of the river. The drift of the beach seems always to be toward the west, and these spits that shut up the streams are uniformly in that direction, the river being continued sometimes behind the spit for several rods before, by entering the gravel, it is finally lost altogether. (Compare figure 2 of plate II.) The coast line is hardly broken by the river, especially in the existence of this spit, but the valley seems to be in the eroded place of one of the more amygdaloidal layers of the igneous formation that forms the coast line. There are several falls a short distance up this stream, as there are up all these streams, making the north shore more abundant in water-power than any other part of the state.

The rock of Two Island river continues to form the coast to Cross river, the shore ascending from the water with the slightly varying dip, from three to fifteen feet, but rarely having perpendicular walls.

At Temperance river the same beds are cut through by the river, and the underlying amygdaloid allows of the sudden recession of the lowest rock-barrier within the line of coast, so as to form a small rock-bound amphitheater, rising suddenly and perpendicularly from the lake-level on all sides, forming a good harbor for small boats. This is entered through a little niche in the rocky coast, in quiet water. The water of the river descends by a short plunge over the next lower layer of trap-rock directly into the water on a level with lake Superior. Above the fall is a narrow gorge, only visible on ascending the rocks, crooked and filled with cascades, through which the river rushes with a rapid current, throwing a white spray on all sides. This gorge exhibits some large pot-holes, some also worn and broken, thus showing how the river has eaten into the rock and excavated this gorge. There is no larger stream between this and the St. Louis.

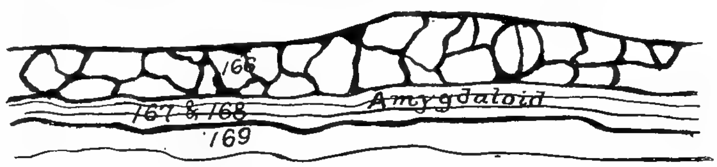

FIG. 56. GLOBULIFEROUS WEATHERING JOINTAGE NEAR TEMPERANCE RIVER.

Ascending the Temperance river the layers of the copper series can be seen constantly rising, the dip of the formation being greater than the descent of the river, so that by the time the falls are reached several hundred feet of thickness of bed have been passed over. They all have a general resemblance to themselves, being a trap like Nos. 163, 164 and 165, but in places, or rather in beds, amygdaloidal, these beds coming in with a rough alternation, but not with continued regularity. They may have been partly sedimentary, but they show no outward signs of it, except, perhaps, this kind of stratification—which still may be due to successive overflows of lava. Indeed the amygdaloid beds seem to alternate in a manner as if a flow of lava became amygdaloidal by degrees toward the upper surface, the denser portions passing upwardly gradually in the more open, but the open parts passing upwardly suddenly to compact, non-vesicular layers. There is also a marking on the upper surfaces of some of the amygdaloidal beds, which seems to show the effect of cooling from a molten condition. These marks or wrinkles are transverse to the direction of the dip. They are in a finer grained rock, though on the upper surface of the amygdaloidal layers, and seem to be of the same

NOTE.—Figure 56 illustrates the manner in which the heavy beds sometimes disintegrate. The rock No. 166 is the same that forms the gate to the amphitheater at the mouth of Temperance river.

kind of rock, though redder, as the amygdaloid itself. They are seen at four different horizons, and overlie uniformly beds of a foot or a foot and a half up to three feet and a half of amygdaloidal trap, with which they are connected by slow changes into the same structure. They are themselves somewhat amygdaloidal, but with much finer and fewer amygdules. There is sometimes a thin belt, or interrupted stratum, of highly and coarsely vesicular and amygdaloidal rock immediately under the wrinkles, which causes the separation of sheets of the wrinkled finer rock from the rest of the bed. These wrinkled surfaces, which are transverse to the supposed flow of the molten rock toward the lake Superior basin, may have been caused by the superficial cooling of a film of rock on the surface of the flowing lava. The lava continuing to flow—toward the lake valley—the film was wrinkled by being obstructed by its own stiffness, as cream is wrinkled transversely on the edge of a pan as the milk runs out below. As the liquid below moved on, the crust somewhat stiffened, could not so freely move, but yet was not hard enough to maintain its position. By friction it was carried on more slowly, but wrinkled transverse to the force moving it. The crumpled layers are about an inch thick, but sometimes two or three are infolded upon each other, making a crumpled layer of three or four inches. They are much finer and denser in grain and structure than the beds on which they lie, and are of a redder color. The convex sides of the wrinkles are upward. The trap here is all of a dark color, as distinguished from the red trap and laumontitic amygdaloids, and overlies the red amygdaloids between here and Poplar river. The amygdules are calcite, stilbite, mesolite, with chlorite in its various stages of change. Sometimes embraced in these wrinkled layers are lenticular areas or patches, one-half inch to one and one-half inches thick, of a red grit, resembling the red sandrock with which these traps are associated, and within the amphitheater, near the water on the north side, is an irregular triangular patch of ferruginous, thin-bedded shale, itself amygdaloidal, lying under a layer of dark trap and over the beds that show these wrinkled surfaces. Five layers of alternating trap and amygdaloid are visible between the lake and the first fall, somewhat less than one-quarter mile up the river.

No. 166. Heavy, dark trap, forming the gate to the amphitheater at Temperance river, from the top of the bluff, twenty-two to twenty-five feet.

No. 167. Ochery, red, shaly beds of grit in a niche in the disturbed amygdaloid under the beds of No. 166, zero to three feet; with fine argillaceous films.

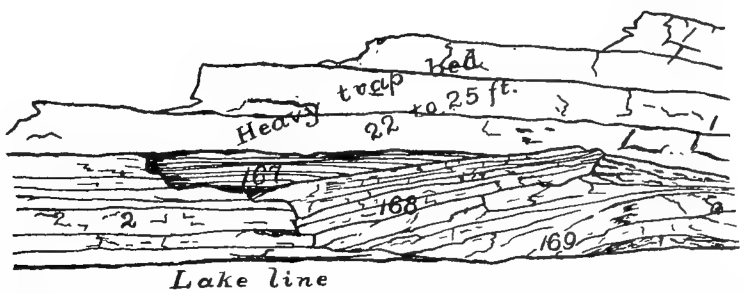

FIG. 57. SUPERPOSITION OF ROCKS AT THE MOUTH OF TEMPERANCE RIVER.

No. 168. Amygdaloid of calcite; same as the next, but taken higher in the beds.

No. 169. Upper surface of an amygdaloid layer, rising like a dome near the water, exposing three feet.

No. 170. Wrinkled upper surface of an amygdaloid layer, from near the mouth of the river.

No. 171. From the lowest layer exposed at the falls, about one mile up Temperance river; outwardly a trap undistinguishable from all the rest at Temperance river. This fall is on N. W. ¼ sec. 30, where a little creek joins the river from the northwest.

The gorge of this river, and the falls, taken with the cascades, the pot-holes and the rapid descent, are altogether a most remarkable combination of picturesque river erosin. They are in the midst of inaccessible and wild scenery. The gorge is so narrow it can be stepped across, the only danger being to secure footing on the other side, for a failure would precipitate a man down a gorge from 50 to 100 feet into a foaming river. In one part of this gorge, which is about sixty rods long, are several perpendicular falls of the water, some of them being into large pot-holes, from which the water whirls and plunges downward obliquely into others. Some of the abandoned pot-holes are on the rock 100 feet above the water, and some are even outside the river gorge, and show where the river has acted formerly.

No. 172. About three-quarters of a mile below the mouth of Temperance river; from a layer of trap that weathers green, is irregularly bedded and in spots is amygdaloidal. This is a little higher than No. 166, in the bedding, but at points further east, and particularly at a point about one-third of a mile east of Temperance river, seems to hold large globular masses, as if of boulders, and at other places seems to be conglomeratic in the same way. Nos. 167 and 168 become a thinly bedded amygdaloid running along the shore between No. 166 and No. 169.

No. 172A. Slickensided stilbite, from this.

No. 173. Northeast corner sec. 28, T. 59-4 W. In a little stony bay facing northeast. This bay is partly shut in by a projecting trap point running northeast, from which this number is obtained. It is an amygdaloidal trap containing stilbite, thalite, calcite, with some laumontite in amygdules and in nests and joints. The

stilbite occupies the larger cavities, or lines them, the thalite being as filling to amygdules or in geodes of heulandite. The rock itself is roughly bedded, and dips toward the lake at an angle of about 10°.

No. 173A. Heulandite, taken from No. 173.

No. 173B. Weathered mesolite from the beach in the bay on section 28, near No. 173.

No. 174. At five miles from Temperance river (sec. 12, T. 59-4 W.) the bluffs rise from twenty to forty feet, and are made up of trap and amygdaloid, sometimes having the globuliferous jointage noted near Temperance river (see figure 56, page 328); the amygdaloid also sometimes being conglomeratic, containing harder masses of more compact rock; still somewhat amygdaloidal; and a ferruginous sandstone which seems rather to fill veins and irregular cavities. There is much calcite and laumontite in this amygdaloid. The samples with this number are of the more compact rock in the amygdaloid, and of the sandstone. There are many deep purgatories and arched passages and buttressed porches along here. The globuliferous jointage noted is not due to the existence of boulders in the mass, but to a natural separation of the bed along conchoidal or curving surfaces, as it prepares to disintegrate. These all dip toward the lake about 15°.

No. 175. At six miles (about) east of Temperance river (the coast all the way from that river being continuously rocky with the same as seen at Temperance river), the conglomeratic beds appear on the coast. Here they are more distinctly conglomeratic than at other points. Some of them contain angular and somewhat rounded masses of different texture, though not of much different color or composition, from the mass of the rock. Here there are also lumps of amygdaloid contained in a red sandrock, the amygdules being largely of calcite and laumontite; but the sandstone, which, however, is hardly gritty, but ferruginous and aluminous, makes up less than one-half of the mass. These beds (No. 175) are about six feet thick. They are overlain, in an oblique upward strike from the water, by a bed of trap undistinguishable from the trap that occurs frequently along here, and are underlain by the next.

No. 176. A tough, thin-bedded rock, containing much iron, and having a red mineral (heulandite?) separating its frequent joints, so as to appear blood-red on approach, or spotted blood-red. Its general color is dark-brown or black, and it is seamed with calcite, and laumontite, the second including the former as between the walls of a vein, the veins being rarely more than one-quarter inch in thickness. It is finely amygdaloidal with the same minerals; twenty-two feet thick; resembles the Two Harbor rock.

No. 177. Is another bed of amygdaloid and sandstone, eight feet thick, underlying No. 176. (See No. 626.)

No. 178. Shows four feet, but beyond, at another bluff, rises so as to show ten feet. It is a less amygdaloidal state of No. 177, and lies below No. 177. The last two numbers are got about fifty rods east of Nos. 175 and 176. There is an isolated pillar of No. 176 standing on a broad pedestal rising about twelve feet high, about forty feet from the shore.

Round the next little point, about twenty rods further, these beds are broken and confused, the dip changing to the southwest. There are here broken upward bends, or domes, of soft amygdaloid that encroach on No. 176 so as by weathering to make deep purgatories with buttresses of No. 176 separating them. After a short interval the beds go back again, and retain their usual dip toward the lake. (Compare No. 626.)

No. 179. Comes in below these amygdaloids, at about a mile west of Poplar river; a greenish, heavily bedded doleryte; rising about ten feet and returning near the water, as the coast line crosses the strike of the beds. The coast between Temperance and Poplar rivers is very picturesque and interesting, but difficult for small boats. The trap and amygdaloids take a thousand fantastic shapes, as the line of the lake level cuts across the undulations of their bedding and change of dip. Sometimes the bridge of trap, as it runs down to the lake, is entirely eaten under, forming deep purgatories; or it sometimes breaks down, leaving islands of rock just off the line of coast. Sometimes island, bridge and all are taken away, and the waves break on the base of a high bluff that often rises perpendicularly from the water, or is skirted by a little, short pebbly beach, a rod or more inside the line of islands.

No. 180. From the middle island at the mouth of Poplar river. Here the strike of a heavy layer of trap runs along the shore, but about six rods lakeward it exists as islands and a reef left by the waves, thus enclosing a small and imperfect harbor for small boats; contains mesolite.

No. 181. Underlies No. 180 and does not vary much from it, except in being more evenly and more thinly bedded; and in separating into closer joints, so as to disintegrate, leaving No. 180 to stand alone, and really causing its more rapid demolition. Nos. 180 and 181 form substantially one rock, and are both what has been styled trap along here. In weathering they become very rusty, when not under friction, and brick-red, crumbling in little red globules. These beds are twenty-four feet thick.

No. 182. Is directly under No. 181, and is a shaly, red, easily crumbling rock, apparently of not uniform thickness, but, in one place, is about eight feet thick; on the east of Poplar river, associated with a red conglomerate.

No. 183. A highly amygdaloidal rock, exposed below No. 182, but ascending, at other places when exposed, so as to "pinch" out No. 182, and almost uniting with No. 181. This crumbles and gets brick-red on weathering on the beach. Nos. 182 and 183 seem to be the equivalents of Nos. 175, 176 and 177, but there is here no layer like No. 176.

No. 184. A vein of breccia (?) about eighteen or twenty inches wide crosses the face of a crumbling, greenish trap, running N. 40° E.; similar to a rock that seems to have been embraced in the vein; one-eighth of a mile east of Poplar river. This vein is nearly white, and is made up of calcite, thalite (?) and laumontite.

No. 185. Laumontite and stilbite; each associated with calcite, occur in large nests in the rock, of about the same beds as No. 183, at three miles east of Poplar river.

No. 186. A little further east can be seen a very interesting instance of the manner of weathering of the trap beds. This is similar to what has been mentioned before, and styled globuliferous. (See figure 56 on page 328.) The rock seems to decay to a considerable depth, and to assume a globular structure, the little globules being rough exteriorly, and generally about half an inch across. This cannot be due wholly to any peculiarity of circumstance in exposure, since here we have an opportunity to see alternations of rough and globular weathering and of smooth weathering alternating in beds one above the other, the beds being otherwise outwardly undistinguishable. The rough and globular layers show these characters, both near the water and also as they rise obliquely across the bluff, and the same is true of the smooth weathering layers. Samples show both.

No. 187. An amygdaloid, containing amygdules of zeolitic minerals, as stilbite and mesolite, as well as delessite. Some of the crystalline nests are large, the mesolite appearing agate-like. Some of the mesolite is of the variety lintonite. This is at Eclipse beach.

No. 188. A greenish doleryte that weathers softer, slippery and smooth. It occurs suddenly at first, on a point running northeast (Eclipse beach), and enclosing a little bay, being a bed of overflow of igneous rock. It embraces corrugated surfaces, like those seen at Temperance river, especially at points a little further east, where it becomes closely associated with No. 187, which it overlies. It seems to embrace parts of No. 187, and then to take its place. The corrugated areas are small, the wrinkles curving, and being in various directions, sometimes like an inverted basin. (The equivalent to No. 623.)

With various unimportant alternations between Nos. 187 and 188, or rock undistinguishable from them, but with a dip toward the lake of 8° to 15°, the coast continues rocky from the last point to Cariboo point (sometimes styled Black point), and generally low, with only occasionally a bluff rising ten or fifteen feet. At Spruce river a high bluff rises along the right bank near the mouth. (See figure 58.)

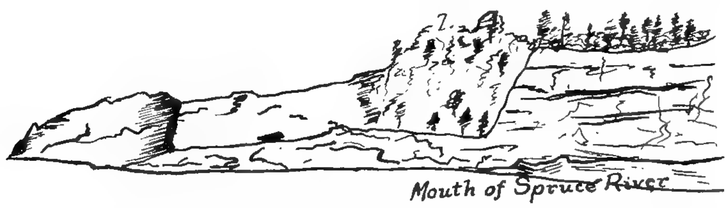

FIG. 58. POINT AND BLUFF WEST OF SPRUCE RIVER.

No. 189. Cariboo point, S. W. ¼ sec. 11, T. 60 2 W. The rock of the point is represented by this number, and is of the same horizon as No. 188. On the east side of the point this rock is basaltic radiatingly, and shows a thickness of eight to twelve feet. The basaltic columns gradually give way to a bedded stricture toward the north. In some places it is fine-textured, especially near the top, and there shows the corrugations of surface that has been supposed to be old lava crusts; but generally these are smoother than those seen at Temperance river. This dips toward the lake at an angle of about 10° and lies on the next.

No. 190. A brownish-red sandstone, or shale, so fragile as to fall to pieces by handling; within the bay enclosed by Cariboo point. This has a cross-lamination, and toward its junction with No. 189 is much less siliceous, and more aluminous for a thickness of about twelve feet. Its dip causes it to disappear, and its fragile character to become covered, within four rods of its first appearance, under No. 189. It reappears slightly about fifteen rods within the bay, having the same dip. Then, for a little more than a quarter of a mile, the coast is low and only pebbly. Beyond that, however, the shore shows the same rock again as on the west of Cariboo point, though at first appearing more brecciated or conglomeratic. This sandstone layer (No. 190) is doubtless the same, or very nearly on the same horizon, as some of the laumontitic amygdaloids so frequently seen further west, the conditions of metamorphism at this place not having been such as to generate zeolites. It is plain that not much heat accompanied the overflow of No. 189, as it seems not to have affected No. 190, the transition being abrupt from one to the other.

No. 191. The rock which first appears on the east of Cariboo bay continues to Cascade river, forming a line of low coast. This number represents it at Cascade river. It there overlies the next.

No. 192. A reddish-brown amygdaloidal, finer-grained rock than No. 191; forms a low outcrop on the right bank, near the mouth.

Trap-rock, like No. 191, occupies the coast, without any intermixture of amygdaloid, forming a low, dark, coast-line to the point half way between Cascade river and the point on the west of Good Harbor bay. At this midway point No. 191 is broken into, allowing the formation of a deep bay (Lover's bay), while its direction near the lake level can be seen in a small island east of the point. Under No. 191, within this bay, are beds of less firm rocks which, by the erosion of the lake, cause the destruction of the overlying beds, which, as the dip rises, make the top of the bluff at the head of the bay, rising fifty or sixty feet. This bed is greenish black and contains mesolite; sometimes basaltic and sometimes bedded, with a few spots of enclosed reddish amygdaloid. In other places the doleryte itself, more compact and of a reddish-brown color in patches, as if brecciated or irregularly cooled, shows lava-crusts and included angular and rounded masses. In these places the surfaces are firm, rough and many jointed. In other parts the dark green color returns, and the rock weathers smooth under friction, but in the weather only it crumbles. A lower bed of amygdaloidal trap, with purgatories, generally low, but rising near Terrace point to eighteen or twenty-five feet in hight, extends from Lover's bay to

Good Harbor bay. Near Terrace point it presents much the character and confused composition as seen at Lover's bay, being reddish-brown and brecciated, the top being more dark and firm, like a true doleryte, and containing mesolite, etc.

No. 193. This is from the very point, which sharply encloses Good Harbor bay; a green-weathering doleryte, containing thomsonite and mesolite (V. No. 535). This dips conspicuously, and overlies a brown sandstone, or shale, which also dips toward the lake and runs 1,400 feet along the shore.

No. 194. Brown sandstone, from Good Harbor bay; aluminous; by making measurement along the beach the outcrop is found to extend 1,400 feet, with an average dip of 8° 30′ toward the lake; by trigonometrical calculation the thickness of the strata is ascertained to be 206.9 feet, as exposed, but the thickness must be considerably more, owing to the non-exposure of rock in an interval of nearly 1,000 feet before the underlying firm beds appear in the beach further north. This is probably the equivalent of the sand-rock at Cariboo point, but may be another stratum. It is very frail, and although sometimes a little slaty, it will easily fall to pieces if taken in the hand.

No. 195. Is a firm but porous amygdaloid, the pores and seams sometimes being quartz-filled and iron coated. From the north side of the first little creek in Good Harbor bay, underlying No. 194, but not immediately. Very soon the shore becomes rocky with a brown, rough rock, irregularly jointed and compact, appearing like that at Two Harbor bay. This soon becomes irregularly mixed with the usual doleryte which extends to the second little creek, where there is a short pebbly beach. The same rocks soon return. The shore is rocky nearly all the way then to the point that encloses the bay in which Fall river empties.

No. 196. From the rocky island off the point that encloses Good Harbor bay; a doleryte containing mesolite; similar to, and in the line of bearing of, No. 193.

No. 197. A reddish brown rock, closely jointed, and also breaking sharply with a conchoidal fracture; very rough exteriorly, *i. e.*, with sharp projecting angles that tear the boots, but not porous or open; forms the point and coast line first east of Good Harbor bay, east of No. 195.

No. 198. After passing a little point and a bay facing east, a green weathering rock, finely jointed, and having an interior brown color, appears along the shore, and finally shows a basaltic structure and coarser grain near Fall river, where it stands out in the beach, and was illustrated in Norwood's report. Samples are from the basaltic parts. At some places the rock along here, west of Fall river, is slaty, and has a green color. Rock No. 198 extends to Grand Marais, generally showing its basaltic columns (figure 1 of plate KK); but along the beach at one point having an amygdaloidal red rock below it.

No. 199. The same as No. 198; from the basalt at Grand Marais. Contains plagioclase, diallage, magnetite, hæmatite, ferrite, apatite.

No. 200. Samples of copper-bearing greenstone (gabbro), from N. W. ¼ sec. 24, T. 61–1 W., up Fall river. This heavy-bedded rock has slickensided seams, or thin filling between layers. These seams contain much chloritic mineral (delessite ?), some layers of it being one-half inch thick, with stilbite closely mixed with it, and also small quantities of calcite; the copper occurring in the massive, hard greenstone, or doleryte, in the form of thin spangling sheets once or twice the thickness of paper, or even one-quarter inch thick. The sheets sometimes embrace three or four square inches in area, This location was wrought by Johnson and Maguire in the summer of 1876, and the face of the rock shows perpendicularly about eighteen feet. It probably exists as a dike.

No. 200A. Concretionary masses within No. 200, apparently having a large amount of diallage (?) with olivine, orthoclase (?) and a white radiated zeolite like thomsonite. These concretions are perhaps produced by the inclusion of fragments of No. 201 in No. 200, when the latter was in a fluid state.

No. 201. This, which is cut by No. 200, is the palisade rock, but has fewer of the translucent crystals of anorthoclase than the palisades themselves. It is properly styled a porphyritic, orthoclastic felsite. It is from the mine on Fall river.

No. 202. Green, coarse doleryte, round the east point of Grand Marais; a low exposure in the coast line; with concretions or inclusions of a finer grain. This terminates rather abruptly on the east, somewhat like a dike when in contact with No. 203; but it is not basaltic, nor is the contact abrupt. Nos. 202 and 203 change colors gradually, and in fragments are mixed through a breccia of three or four feet wide.

No. 203. Resembles No. 201, and is much like the Palisade rock. It furnishes pebbles for the beach which are strewn all along, making the beaches at Grand Marais. Dips 5° to 15° toward the lake, or by the coincidence of the coast line it appears sometimes nearly horizontal. Sometimes it resembles the siliceous gray slates of Beaver bay (No. 125).

No. 203A. From a vein of laumontite in No. 203.

Nos. 204, 205 and 206. Transition rocks in the order numbered, between Nos. 202 and 203.

No. 207. A doleryte like No. 202 which suddenly comes in crossing the beds of No. 203, forming a little point in the coast. This dike is about 200 feet wide, and gives place to the beds of No. 203 again on the east.

These run perhaps 500 feet, when another similar dike crosses them. There are six such within a mile along here, and some are basaltiform obliquely. They run E. 15° S.

No. 208. This rock occurs much like a dike at first with perpendicular jointage, or basaltic structure in beds, but soon larger bedding, crossing these, cut it, and cause the rock to all appear bedded. This is fine-grained and brown, and is about twenty-five rods from the last of the dikes already mentioned. This becomes a bedded rock, like similar beds seen before, having sometimes the appearance of the Two Harbor rock. It slopes toward the water. Just beyond the mouth of the third little creek (on the Lake Survey chart) these beds become disturbed and brecciated and even tipped in the other direction (southwest) and are crossed by a dike of

FIG. 1. BASALTIC COLUMNS IN DIABASE, GRAND MARAIS, NORTH SHORE OF LAKE SUPERIOR. (p. 332.)

FIG. 2. PRESENT AND ABANDONED BOULDER BEACHES AT HORSESHOE BAY, NORTH SHORE OF LAKE SUPERIOR. (p. 340.)

FIG. 3. VIEW AT THE WEST END OF KEKEQUABIC LAKE, SHOWING (BY WEATHERING) THE SILICEOUS VEIN-LIKE RETICULATIONS FORMED BY METAMORPHISM IN THE GREEN CLASTIC SCHIST. (p. 450.)

doleryte like No. 207, about eighteen feet wide. Previous to this (further west) they show patches amygdaloidal; but just on the east of this dike there is much amygdaloid with laumontite. Just before reaching the mouth of the fourth creek another dike like No. 207 crosses these beds running in the same direction as those before seen, and throwing up the firm heavy beds of No. 208 at a high angle. This dike is basaltic perpendicular to these beds by being cooled by them. This last larger dike is only exposed near the water and its exact contact with No. 208 is invisible. It is exposed about fifty feet.

No. 209. This is from still another similar dike of doleryte cutting these beds or interbedded in them; the columns sloping obliquely inland. This is prominent and conspicuously basaltic perpendicularly to the highly tilted beds of No. 208. This dike or bedded trap rock runs nearly east and west, No. 208 dipping into the lake at an angle of about 45° in patches perhaps twenty rods, becoming less conspicuous toward the east, and at last disappears a few rods west of the mouth of the Devil's Track river under a low, red, pebbly beach, the pebbles being from No. 203, which here appears again. (See figure 1 of plate II.) This beach continues for a mile or more, occasionally allowing the exposure of the rock in place, to the southeast corner of sec. 1, T. 61-2 E., where appears in the midst of the shingle of the beach a different rock, viz.:

No. 210. This is in a low exposure. It is a firm, smooth-weathering rock, with a brown color and has an abundant green mineral; apparently one of the igneous beds.

No. 211. Is from the same beds as No. 210, but from the point next west of Kimball's creek, known as Cow Tongue point. These beds here rise about eighteen feet, shutting in a bay that faces east. This point is on S. E. ¼ sec. 9, and the coast is rocky, with the same rock from No. 210 to this place.

No. 212. After a short red-pebbly beach in this bay, this number appears in low outcrop, and is the same red-rock as No. 203, showing here nearly a horizontal bedding, running below No. 211.

No. 213. From the extremity of Fish-hook point, near the centre of sec. 16, T. 61-3 E., eleven miles from Grand Marais.

No. 214. Similar to No. 213. From sec. 1, T. 61-2 E., at the mouth of a little creek, west of No. 213.

No. 215. Half a mile west of Fish-hook point. These three (Nos. 213, 214, 215) all appear to be modified forms of No. 203. Fish-hook point was formerly an island, but the lake has formed a continuous beach deposit running north, and enclosing triangularly a lagoon, as well as toward the southwest. The rock here resembles the rock No. 212 in mineral composition and aspect, and is probably closely associated with it, but its structure is different. It is fissile, but generally only horizontally so, or with an obliqueness to the real bedding, which dips gently toward the lake. It is firm against the hammer and against the weather, but is filled with old cracks and joints that make it almost impossible to get a fresh break. It has a red color outwardly, like the rest near the water, except in the joints, which are blue-black with iron-shot (as Norwood describes such); but away from constant wave-action it is black. It is finely porphyritic, with stellar spangles of feldspar, and with isolated crystals which weather nearly white.

No. 214. Is of similar rock, but more firm and crystalline, weathering red, and having some white amygdules. This has a low, inconspicuous outcrop, like others of No. 203, running along two or three hundred feet and dipping a little south of east. No. 215 is from a little point within the broad bay, nearly on the west side of the same section, where it rises about six feet, and, running along the beach three or four hundred feet, weathers red, like the rest, furnishing some of the beach pebbles of that color. In the lake opposite Nos. 214 and 215 can be seen a basaltic rock off shore, which does not appear on the beach and may be the extension of Nos. 210 and 211 forming Cow Tongue point.

No. 216. Is a greenish-brown rock with curling internal structure, containing quartz and amethystine nests, from the westerly of the two little points west of Brulé river, and before reaching either island, where a little stream enters the lake. It is a short outcrop rising about five feet in the midst of a red beach. This is an igneous rock; and the next point is of the same, also the little island off it, which is in the line of bearing.

No. 217. In the midst of a red beach, extending from the last point, is an occasional exposure of this red rock, which within is brownish-red, fine-grained, and has the same purplish quartz (?) as noted in No. 216, in round amygdules, yet is plainly different from No. 216. This is a conspicuous outcrop within the bay between two streams. The strike of the trap (No. 216) can be seen under the water of the bay.

No. 218. The rock of the point, near the Brulé river, off which lie the principal islands. This is a brown, conchoidally fracturing rock, fine-grained or crypto-crystalline, with small quartz-lined geodes, weathering rough-angular, and black when not under friction. Back from the line of friction, on the beach, old weathered surfaces are brick-red. This is very similar to No. 217.

No. 219. A little beyond the last locality, and just as the rock disappears again, it suddenly becomes slaty or closely-jointed and laminated, dipping S. 10° E., and more enduring. In this condition it forms some of the islands near the beach, and also rises fifty or more feet near the coast back from the water. This is fine-grained and nearly black, hard and tough. The rock of the main island, further out, containing a few stunted trees, is more like No. 218.

These beds seem to have been disturbed by some upheaval, and appear in all respects like those of No. 208, though not so conspicuously exposed. The doleryte dike that might here be supposed on the north of this disturbance cannot be seen. The point at the north of the little stream west of the Brulé, and the little island there, are of the same rock as the last.

No. 220. Between these islands and the mouth of the Brulé at a little dull point is a bluish gray rock, weathering green, fine-grained and hard. The outcrop is rather closely jointed and in some spots it is reddish

brown. This rises about six feet, but only runs five or six rods. The beach to the west of this is mainly of a red color, but has blue pebbles also from this rock. At this place the blue and red are about equally common, but the red gradually disappear in going east (V. No. 539).

No. 221. A short distance east of the Brulé (perhaps twenty rods) is a coarser rock resembling gabbro, which is heavy and crystalline. This is not certainly a dike, but it may be, its form and extent not being visible.

No. 222. The last seems to overlie, or to pass into, this. This weathers into a green color, but sparkles all over with what at first appears like mica, but in other respects it is like the last, becoming coarsely laminated when weathered. A little further east these two rocks (Nos. 221 and 222) can be seen in a bluff rising about fifteen feet, the latter being under the former. This rock continues, with increase of the characters of No. 221, and forms two or three little points within a mile east of the Brulé, rising sometimes fifteen or twenty-five feet. The intervening bays are occupied by large, rounded boulders of the same, with little rock exposure in them, or they are pebbly.

No. 223. The rock of the last continues to the high, round point four miles east of the Brulé, and then becomes basaltic on the side facing Sickle bay, rising about thirty feet perpendicular from the water; the intervening coast being low, sometimes exhibiting the coarse dark beds of this rock, but not becoming basaltic (V. No. 540.)

No. 224. Horseshoe bay has a similar basaltic coast line on the west side, rising about sixty feet. West of it are short stony beaches, the strike of the exposed rock being a little further back. Double bay, next east of Horseshoe bay, has a rocky point, dividing it into two parts, and this rock is from this point. The western half of this bay is without rock on the beach, but the hills back rise several hundred feet, having the same rock as the last. This is a fine-grained, metamorphic, brown rock, which is somewhat basaltic like trap, and also rudely bedded.

No. 225. On the most easterly point of Double bay is a crystalline rock which seems to embrace the minerals derived from the sedimentaries mingled with igneous rock material, all coarsely crystalline (V. No. 5).

No. 226. Is from an isolated dike-like exposure on the beach in the next shallow bay. It is a brown or reddish-brown compact rock, finely porphyritic, closely jointed and basaltic, like No. 203.

No. 227. Along the west side of the ridge, or spur (No. 226), is a narrow bed or dike of fine, blue-gray rock, sparingly porphyritic with red feldspar, less enduring than the rock of No. 226. It is nearly invisible. It is narrow, and its line of bearing becomes confused, or blends with the rock of No. 226, being, perhaps, a modified form only of No. 226, due to different influence in upheaval, or to unseen contact with the accompanying igneous rock. This outcrop is between the first and second creeks in this broad bay.

On the little point between the second and third creeks is a low exposure of rock that resembles No. 223, mainly broken into boulders. Also, a small isolated outcrop is just east of the third creek. Otherwise this bay has a pebbly beach. But the broad point that separates it from Cannon Ball bay (similar to Horseshoe bay) has a low, rocky beach of the same rock as the last mentioned, viz.:

No. 228. A heavy-bedded, coarse-grained doleryte (V. No. 540). The east side of this bay is made of the same rock; also, the east point; also, the island east of it, the coast being rocky and low, or rising from six to ten feet, basaltic. The next island, and the coast along, especially the points of the coast, are of the same. It rises into basaltic, coarse beds in a sharp point on the west side of Red-rock bay, succeeded suddenly by a red, pebbly beach within the bay, strongly contrasting with the dark green or black color which it suddenly replaces (No. 230).

No. 229. Doleryte, like No. 228; from Red-rock bay, west of the red rock, outcropping in the midst of a red, pebbly beach; runs under the eastern Palisades.

No. 230. Red rock from Red-rock bay. This resembles, or is exactly the same as, the Palisade rock. It is porphyritic, with flesh-red feldspar, and with translucent crystals that are prevailingly quartz, but are sometimes quadrangular in section, sometimes square, and have a perfect cleavage. The manner of exposure is considerably like that of No. 226, in a little bay west of this place. This rock has an imperfectly and finely basaltic structure, the joints being two to four inches apart. The relations of the doleryte to this cannot be distinctly seen, but that rock can be seen to the west in the beach, and probably passes below this. This is the rock known as the eastern Palisades (V. No. 620).

No. 231. From a dike of basaltic doleryte a short distance east of the mouth of the Red-rock creek. This dike runs east and west, and is horizontally columnar. It cuts the rock of No. 230, and varies from fifty to sixty feet wide. It is fine-grained, blue-black, and weathers greenish. It embraces patches of the red rock.

No. 232. The first rock that appears in the pebbly beach east of the rock of Red point, near a dike; a brownish-red metamorphic compact rock, sometimes with amygdules of a white mineral, coated with green; apparently underlies No. 230; resembles some of the compact brown rocks seen at Duluth and at many intermediate points.

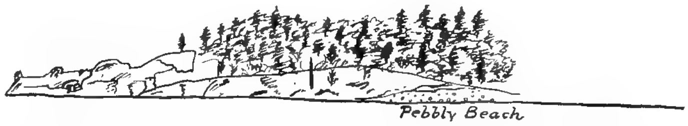

FIG. 59. REDROCK POINT, FROM THREE-FOURTHS MILE EAST.

At Red point, which encloses a deep little bay facing east, and which is high and rocky, with No. 230, another dike of the same kind as No. 231 crosses No. 230. It is about twenty-five feet wide. No. 230 dips into the lake here at an angle of 6° to 10°. It is suddenly discontinued in the bite of this bay, the bluff running in-

land about twenty feet high, the beach being of red pebbles. Just east of this bay are two or three other dikes of the same kind, and several islands formed by them; also some sharp, narrow points.

No. 233. From a dike, near No. 232, twenty-one feet wide, horizontally columnar, running north 15° east and projecting into the bay seventy-five to ninety feet, of a blue-black color.

No. 234. From a dike eighteen feet wide, running east and west, "hading" a little to the south, cross-columnar, cotemporary and blending with the dike No. 233, the structure of the two running together; of a brownish-black color. This rock is like a melaphyre, but No. 233 is not.

No. 235. A rock similar to No. 232, cut by the dikes, having a slaty structure without any dikes; forms the beach next north of the dike No. 234 which is out in the water.

No. 236. From a dike twenty-one feet wide; a fine-grained, black basalt, running out into the lake about 250 feet, but often in the form of islands that occur a little out of line. The basaltic structure of this is very irregular. In some places it is fine and in others it is coarse; runs N. 15° W., being intersected by the dike No. 234, apparently in the same manner as No. 233.

No. 237. Is from a curious isolated mound of brown and firm rock, standing between the beach and the lake, a short distance east of the dike No. 236. It is curvingly bedded and laminated; rises eighteen feet and extends eighteen feet on the beach, shaped like a haystack. It has a reddish-brown color. Its manner of occurrence is like that of the rock No. 226.

No. 238. Is from a curving, slaty condition of the same rock, rising ten feet; there is much confusion and twisting of the slaty or laminated beds, the whole formation being broken up. Nos. 237 and 238 continue east about half a mile, and gradually become more dense, or non-slaty, yet fissile, hard and angular, crossed by several smaller dikes running east and west, or southeast and northwest.

No. 239. Shows the condition of the same beds in process of this change. Here also are slaty spots, also compact firm spots, but instead of red the general color is brown, weathering faint-red in the old joints when freshly separated.

No. 240. A reddish-brown, fine-grained rock, breaking conchoidally, but a further weathered condition of No. 235.

No. 241. Becoming black, and almost undistinguishable from fine basalt.

No. 242. Next appears a dike about 100 feet wide, cutting these beds, running nearly east and west. This seems to have spread largely, at least in its effects, on either side, and the adjoining rock appears like basalt, but still seems to be only a changed condition of No. 235.

Nos. 232 and 235, and their modifications, run under No. 230. There are spots in No. 235 that appear like the aluminous mud-spots seen in No. 194.

The alternating phases of Nos. 239, 240 and 241 continue, with occasional dikes, or overflows of rock like No. 242 to Deronda bay, appearing like the Two Harbor rock.

No. 243. From the west point of Deronda bay; a fine-grained, hard, nearly black homogeneous rock, of doubtful origin; probably one of the forms of the rock No. 235, etc. It is rather bedded, but not basaltic, and lies on an amgdaloid, viz.:

No. 244. A reddish-brown amygdaloid, with green amygdules irregularly passing into

No. 245. Which is of the same color but has nests of a lighter mineral, and is mainly a non-amygdaloidal rock. Just west of the west point of Deronda bay is an island of basalt, near the shore, mainly made up of rock like No. 242, in an arched position, the waves having eaten under the arch into the softer beds, producing a natural bridge. The head of Deronda bay has a pebbly beach, but the east side is rocky, with a dike that "hades" to the south and is thirty feet wide, running nearly east and west, and cutting rock like Nos. 244 and 245 (or Nos. 246 and 247), there weathering out as purgatories, and lying nearly horizontal.

No. 246. About three-quarters of a mile east of Deronda bay, at the mouth of another little creek, is a bluff of rock made up of Nos. 246 and 247, but running but a short distance. No. 246 is soft and green with considerable prochlorite (?). The lower ten feet of this are somewhat amygdaloidal with calcite and quartz, coated with green, but the upper ten feet are massive or heavily bedded, but breaking easily into sheets; overlies the next.

No. 247. Amygdaloid; rock like the last but having a more amygdaloidal character.

No. 246A. Calcite, saccharoidal and flesh-colored from No. 246. These beds dip south about 12° East of Deronda bay the second little sharp point is caused by rock like No. 246 dipping south, rising ten feet. The third little point, which occurs after a pebbly beach of half a mile, is produced by a wide doloryte dike running E. 10° S.

No. 248. Is from this dike, which has an indefinite width, at least 200 feet. This rock is porphyritic, hard and massive. On the north side its contact is a fine basalt, and the adjoining rock is an amygdaloid, but only about six feet of the amygdaloid is here. It lies along the dike as if it belonged to it (V. No. 1855).

No. 249. Amygdaloid adjoining No. 248.

No. 250. The west point enclosing Grand Portage bay is low, but has a rocky beach consisting of alternate layers of basalt and amygdaloid rising but little above the water.

No. 251. Underlying No. 250; an amygdaloid of a greenish color. These beds (Nos. 250 and 251) dip south at a low angle and do not extend into the bay. They apparently form the coast line between Grand Portage bay and Deronda bay, there being but little outcrop with a low shore between these places. The west side of Grand Portage bay shows no rock. It is low, the timber growing nearly down to the water.*

* For a description of the lake shore at Grand Portage bay and Pigeon point see the chapter on the Pigeon Point plate.

The drift. The drift deposits of Cook county have not been studied in great detail, and it will be posssible to present here no more than a general outline of these deposits and the glacial history of this region. In the district along the immediate shore of lake Superior, and in that along the international boundary west of South Fowl lake, extending on the west as far south as Brulé lake, the drift is comparatively thin and rock exposures are abundant. South of the international boundary district as far as the top of the steep slope leading to lake Superior, the rocks are more heavily covered by drift, whose maximum and whose average thickness is not known.

Glacial striæ.

N. W. ¼ sec. 27, T. 65–2 W., north shore of lake Louise, -	south 16° W.
S. E. ¼ sec. 28, T. 65–2 W., north shore of lake Emma,	south 7° W.
N. W. ¼ sec. 35, T. 65–2 W., north shore of No-name lake,	south 2° W.
S. W. ¼ sec. 10, T. 63–3 W., reef in Brulé lake,	south 18° W.
S. E. ¼ sec. 20, T. 65–4 W., north shore of a small lake,	south 4° E.

"On the rock which forms the outer part of Grand Marais harbor are numerous parallel glacier striæ and grooves from a few feet to fifty feet in length. There are two sets of these striæ, which cross each other at a small angle. The more prominent and numerous striations run about west, the other set bears south of west. In a number of places west of Grand Marais are found striæ which run west, or a little south of west. South of the Pigeon river all striations run westerly."*

Lately evidence has been accumulating to show that the northeastern part of Minnesota was covered by two glaciers or two glacial lobes moving in different directions. One of these occupied the lake Superior basin and moved toward the southwest, while the other occupied the country to the north and moved in a more southerly direction. The ice from these two directions was confluent in the maximum extent of glaciation, but during the retreat the two lobes formed between them a re-entrant angle north of lake Superior, and the northern lobe retreated more rapidly than the other. Thus, while the lake Superior basin, or part of it, was occupied by ice, to the north was a district which was free from ice. The width of this district is unknown, but it was wider towards the west than towards the east. This district was probably angular in shape (the apex of the angle pointing towards the east), and it increased in size by the apex traveling eastwardly and its two sides southerly and northerly respectively. It is quite probable that the northern side traveled much more rapidly than the southern side.†

During the retreat of the ice each of these lobes formed moraines. These moraines are as follows, according to the descriptions and mapping of Dr. A. H. Elftman.‡ The Highland moraine, formed along the northern border of the lake Superior ice-lobe, runs northeasterly approximately parallel to, and several miles

*A. H. Elftman. *Amer. Geol.*, vol. xxi, p. 100.

† This interpretation of the history of the closing stages of the Pleistocene in this district has been stated more or less independently by several geologists, each one contributing certain facts independently of the others. Those chiefly instrumental in bringing forward the interpretation outlined above are:

J. E. Todd. Paper presented before the Geological Society of America, in August, 1896; *Amer. Geol.*, vol. xviii, pp. 225, 226, October, 1896; *Amer. Jour. Sci.*, ser. 4, vol. vi, pp. 469–477, December, 1898.

A. H. Elftman. Paper presented before the Minnesota Academy of Natural Sciences, early in 1897; *Amer. Geol.*, vol. xxi, pp. 90–109, February, 1898.

N. H. Winchell. Paper presented before the Minnesota Academy of Natural Science, early in 1897; chapters on Carlton county and the Carlton plate in this volume.

F. B. Taylor. *Amer. Geol.*, vol. xx, pp. 111–128, August, 1897.

‡ *Amer. Geol.*, vol. xxi, pp. 90–109, pl. 11, February, 1898.

distant from, the lake shore, The Itasca moraine, formed by the northern ice-lobe, has in Lake county a more easterly direction, and, before leaving that county, it unites with the Highland moraine. East of the union of these moraines a single prominent moraine (termed the Itasca-Highland) continues through Cook county, entering this county in T. 60–5 W. This united moraine has its northern and southern boundaries sharply marked. It averages three miles in width and forms the highest land within the first fifteen to thirty miles north of lake Superior. It is well defined around the lakes at the head of Poplar river in T. 61–3 W.; from the Cascade river in the southeastern part of T. 62–2 W. to Devil Track lake, which lies in the midst of this moraine; in the southern part of T. 62–1 E.; and in secs. 20 and 21, T. 64–4 E., where it crosses the Pigeon river. The courses of the Mesabi and Vermilion moraines, formed by the northern ice, are less satisfactorily known. The first is thought to enter Cook county in T. 62–5 W. and to run northeasterly past the southern side of Hungry Jack lake in T. 64–1 W., and to enter Canadian territory at the west end of Rove lake. The Vermilion moraine is thought to enter Cook county north of Little Saganaga lake in T. 64–5 W., and to cross the international boundary near the west end of Gunflint lake.

In connection with the retreat of the two lobes of the ice sheet, it is very evident that a number of glacial lakes, of longer or shorter duration and larger or smaller size, would be formed, first by the obstruction of the westward and northward flowing streams by the northern ice-lobe, and second by the obstruction of the eastward and southward flowing streams by the ice-lobe in the lake Superior basin. Such lakes have been described in Lake and St. Louis counties, and, when this manuscript was first written, the writer called attention to the evidence for such a lake in the Pigeon River valley. Since then this lake has been described as follows: *

Lake Omimi. Before the ice had receded beyond mount Josephine it retained a lake of about forty square miles in area, lying in the upper valley of the present Pigeon river. The lake bed has an altitude of 1,255 to 1,360 feet above the sea. Its lowest point is thus about fifty feet higher than the upper stage of lake Duluth. The chief deposits consist of stratified clay, exposed along the Pigeon river and its tributaries. Beaches have, as yet, not been identified. The western shores of this lake were formed by high rock ridges. The ice-barrier, during the largest extent of the lake, stood in the vicinity of the western end of the Grand Portage trail. The outlet, which has not been definitely located, was most probably toward the southeast, and closely connected with the ice-barrier, which, upon receding, continually uncovered lower ground. This lake, in part, occupied a portion of the area previously occupied by the northern ice-lobe. When the ice receded from the vicinity of Grand Portage lake Omimi disappeared. The name Omimi is taken from the Chippewa name for Pigeon river.

As Cook county becomes more settled and the land is cleared, it is probable that the shore lines and deposits of other ice-dammed lakes will be found.

Two interesting kames † have been noted in Cook county. One is on the international boundary portage between Rove and Rose lakes, but nearer the former. The portage trail runs on the top of this kame for a distance of fifteen or twenty

* A. H. Elftman, *Op. cit.*, p. 104.

† In conformity with the earlier reports of this survey the ridges here mentioned are designated as kames. As the term esker is now used, these ridges would be called eskers.

rods. The ridge is steep on both sides and over fifty feet high in places. It runs rudely parallel with the valley in which the trail lies.* The other kame is in T. 62-1 W., one or two miles west of Devil Track lake. This is a narrow ridge over a mile long and fifty feet high above the land on either side. It is composed of fine gravel and sand, with a few large boulders.†

Abandoned beaches on the north shore of lake Superior. All along the lake Superior shore, above the present level of the lake, the characteristic features of shore lines are found. These present the characters of the present shore except where obscured by vegetation or erosion. These old shore lines were formed when the water was many feet higher than at present, and they can be seen extending as parallel lines along the hill slopes. These old beaches range in hight from a few feet above the present storm beaches to 607 feet at mount Josephine. In some places, as at Wauswaugoning bay, a beach (here forty-three feet above the present level of the lake) is almost as fresh and distinct as the beach of the last storm. At this place another one, seventy-six feet above the lake, is also very distinct (see figure 1 of plate JJ). Below are given descriptions of some of these abandoned beaches in Cook county.‡

Carlton peak. From the vicinity of the Sawteeth to Carlton peak fairly definite suggestions of two, and in some cases more than two, terraces are obtained by an inspection of the coast from the lake. The country is, however, heavily timbered, and experience proves it to be impracticable to locate them within a reasonable time by crawling through the jungle. On the slope from Carlton peak to the shore the timber has been burnt, and by hard scrambling through the windfall it was possible to reach the terraces and ascertain their elevations approximately by aneroid observations. The figures obtained by this means were 80 and 125 feet, respectively, above the lake, for the rear parts of two very gently sloping terraces that have been cut in a broad embankment of soft material which must have accumulated at still higher stages of the lake. The precise registration of these higher stages was not observed, but the conditions of examination were unfavorable, and it is probable that higher terraces on the flanks of Carlton peak will be found.

Poplar river (Lutsen). The Poplar river cuts through a broad embankment of sand, gravel, etc., which mantles the rocky slope of this part of the coast for many miles. The front of the embankment overlooking the lake descends rapidly to the present shore by a succession of cliffs and cut-terraces which have been carved out of the main embankment at various successively lower stages of the water subsequent to that at which it was accumulated.

The brink of the main embankment is about 116 feet above the lake, and from this point its upper slope rises very gently landward for nearly two miles to an elevation of about 300 feet, where it abuts sharply against a steep range of a gabbro. The general character of the topography and the underlying structure is analogous to that described at Beaver bay, where a broad gently-sloping terrace of incoherent material abuts on precipitous rocky hills at an elevation of about 314 feet. The rear of this broad terrace at Poplar river was only ascertained very approximately by an aneroid observation, so that the figures are not incorporated with the more precise data of the table. The wooded character of the country practically prevented precise observations at points distant from the shore without an expenditure of time, labor and money, which would have been inconsistent with the modest plan of our operations. Although the newer terraces carved in the front of this main embankment face the open lake, they are in the immediate vicinity of the mouth of the stream, and the stream currents have doubtless played an important part in the development of the terraces, supplying and removing detritus contemporaneously with the cutting action of the waves. The terraces and cliffs are all remarkably sharp in cross profile. The terraces are narrow and vary but little from horizontal. The angle of slope of cliffs was carefully measured and three were found to have a declivity of 28°, two of 27°, and one (the lowest) of 32°.

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* N. H. WINCHELL. *Ninth Annual Report*, pp. 79, 80.

† A. H. ELFTMAN. *Amer. Geol.*, vol. xxi, p. 97.

‡ From "Sketch of the coastal topography of the north side of lake Superior, with special reference to the abandoned strands of lake Warren," by A. C. LAWSON: *Twentieth Annual Report*, pp. 181-289, pls. 7-12, 1893.

The questions which centre about these abandoned beaches—such as the names and areas of the bodies of water which formed them, the causes of these bodies of water, and the differential elevation that these beaches have suffered—are questions of far greater import than can be discussed here in the description of Cook county. These beaches have been described and questions concerning them have been discussed by A. C. LAWSON, F. B. TAYLOR, WARREN UPHAM, N. H. WINCHELL and others; much is yet to be known concerning these beaches and the questions that centre about them. Compare, also, G. K. GILBERT: "Recent earth movements in the Great Lakes region," *Eighteenth Annual Report U. S. Geol. Survey*, pt. 2, pp. 595-647, pl. 105, 1898.

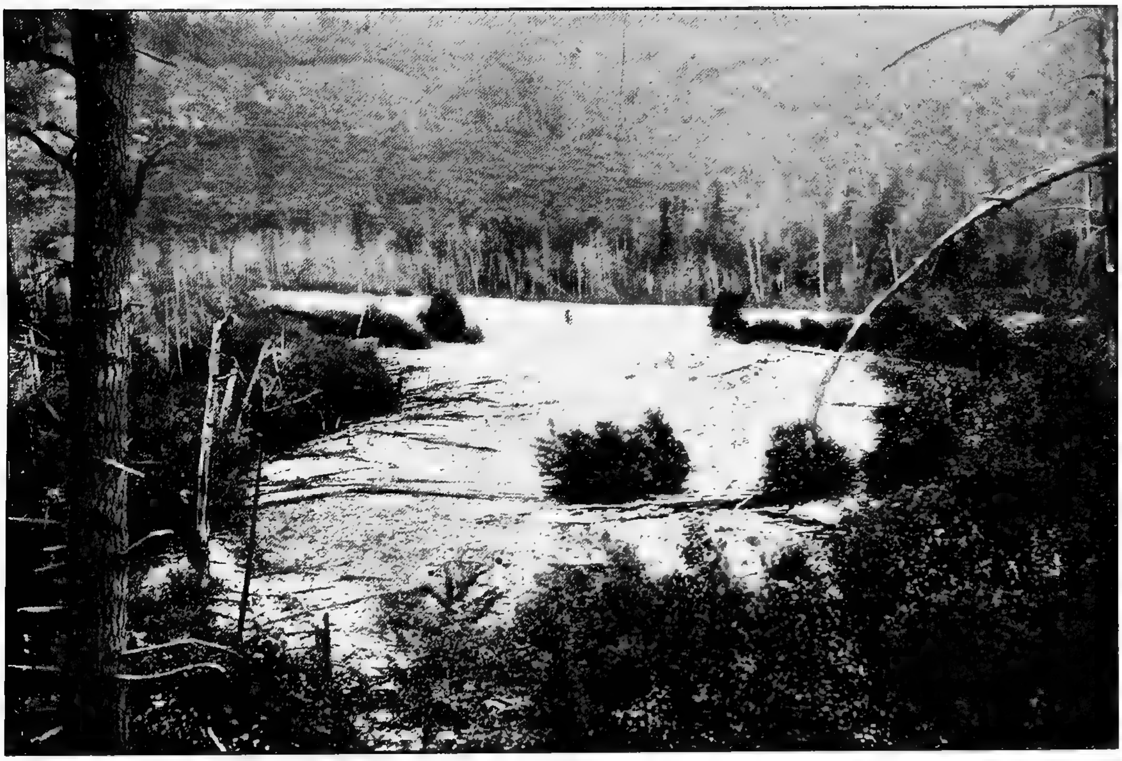


FIG. 1. ABANDONED BEACH, SEVENTY-SIX FEET ABOVE THE PRESENT WATER LEVEL, WAUSWAUGONING BAY, NORTH SHORE OF LAKE SUPERIOR. (pp. 338, 343.)

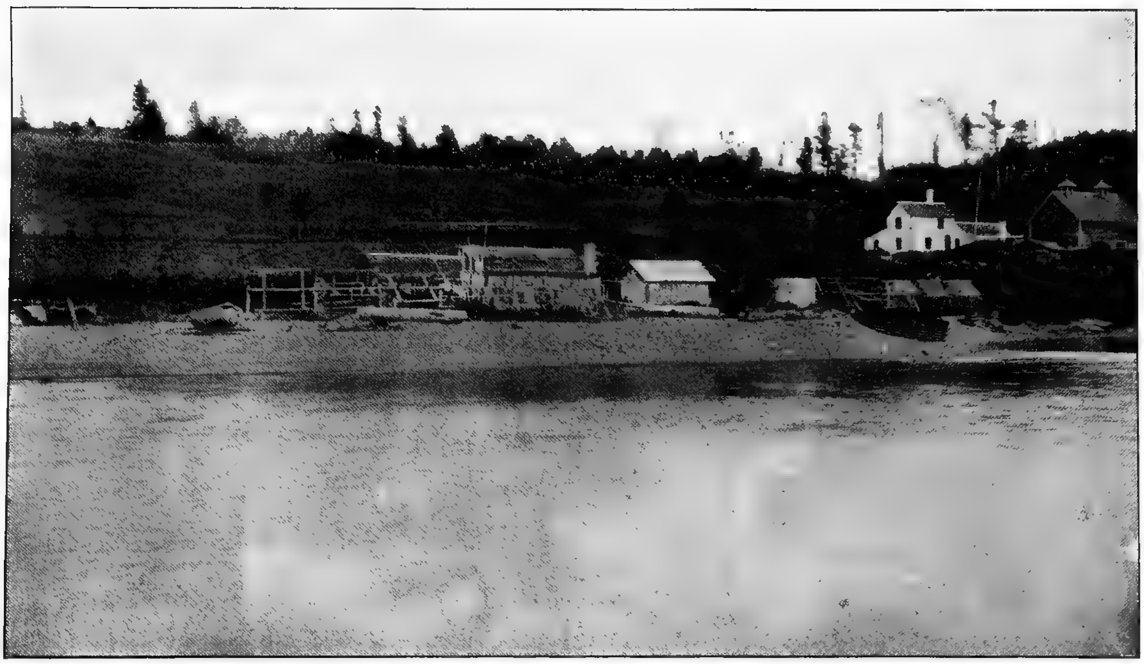


FIG. 2. TERRACES AT LUTSEN, MOUTH OF POPLAR RIVER, NORTH SHORE OF LAKE SUPERIOR. (p. 338.)

The lowest terrace of the series is a wave-built terrace, and is only 6.9 feet above the level of the lake at its rear, where the fishermen's boat-houses stand. Towards the lake it grades into the present shore. The higher terraces have none of the characters of wave-built structures so far as can be discerned. At the summit of this series of terraces and cliffs, just at the limit of the main embankment, is a beach-like ridge with somewhat lower ground behind it and a series of minor, successively lower, parallel ridges on its gentle lakeward slope. This ridge is interpreted to be a barrier beach developed at a favorable stage of the emergence of the coast. The accompanying cross profile was plotted to scale in the field from precise measurements.

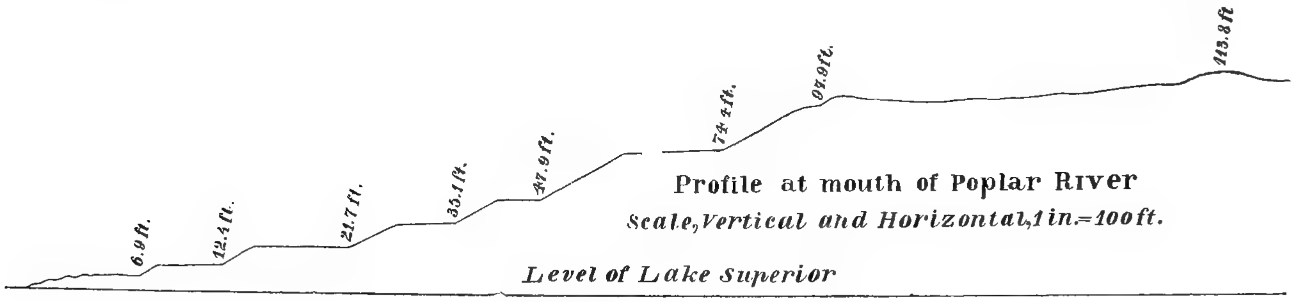


FIG. 60. PROFILE AT MOUTH OF POPLAR RIVER.

On the east side of the mouth of Poplar river only three distinct strand lines have been registered on the front of the main embankment. These are, a well-formed wave-cut terrace facing the lake at an elevation of 78.4 feet; a less distinct terrace, which is seen, in vertical section, where the river gorge cuts it, to be composed of stratified gravels, the elevation of its summit being 99.6 feet; and again a beach-like ridge, the highest line on the front of the embankment, at 116 feet. The terraces at the mouth of Poplar river are shown in plate JJ, figure 2.

Coast east of Poplar river. East of Poplar river two terraces are observed to follow the shore more or less continuously for some miles. Both are covered with timber, but as they are low and not usually distant from the shore, their topographic character is not obscured beyond recognition. Both are wave-cut terraces and have been carved out of a primary embankment which mantles the rocky slopes of the coast. These terraces were found to be susceptible of partial measurement at a fishermen's clearing about two miles from Poplar river. Here the brink of the lower terrace is 14.5 feet above the lake, the front limit being a steep sea-cliff rising from the present shore. The terrace is 150 feet wide and at its rear has an elevation of 17.8 feet, thus exhibiting a slope of about 2 in 100. From the rear of this terrace another sea-cliff rises with a slope of 37°, and the brink of the second terrace is 37.5 feet above the lake. The terrace runs back under the beach apparently nearly flat. The elevation of its rear portion was estimated to be six feet higher than its brink, thus making the shore line about 43.5 feet above the lake. The low sea-cliff which rises above the present shore and limits the lower terrace lakeward is rather a striking feature of this part of the shore, being a vertical scarp of the old embankment material resting upon rock varied in places by shorter stretches in which the cliff is wholly rock or wholly embankment gravel.

Good Harbor bay. The next locality along the coast where the ancient strand lines are sufficiently recognizable to be measured is at Good Harbor bay. The bay is open to the east and northeast and presents on the maps but a small jog in the generally uniform trend of the shore. The west side of the bay is overhung by a sea-cliff of very slightly inclined beds of red and brown shales and shaly sandstone, which rises vertically to a hight of fifteen feet. Between the base of the cliff and the shore line there is a narrow and low beach of shingle derived chiefly from the cliff. Above this sea-cliff there is a terrace about 100 feet wide and twenty feet high at its rear, which is thickly strewn with shingle. Immediately above this, with a low cliff between, is another terrace twenty-five feet wide and 27.2 feet high at its rear, and also cut out of shingle and gravel. A third sea-cliff cut out of irregularly stratified gravels and sands of a primary embankment rises above this for about fifty feet. Above the summit of the cliff the ground rises gently in a rolling succession of beach-like ridges for several hundred feet horizontally and then grades into a distinct terrace abutting against the higher slopes of the hill at an elevation of 115.3 feet.

Grand Marais. The pinkish acid volcanic rocks of the vicinity of Grand Marais have by their mechanical disintegration along the sea-cliffs afforded an abundance of shingle and gravel with which the waves have banked up a fine series of beaches. These have been arranged in parallel ridges in the form of a beautifully distinct and typical wave-built terrace. As this terrace encroached upon the area of the lake the space between the shore and the rocky island upon which the lighthouse stands was spanned by a spit, and the construction of the terrace was limited to the northeast side of the resulting bar, since the latter closed in a bay, the only entrance to which is by a deep channel between rocky points through which no shore drift could enter (see plate HH, figure 4). Within the bay at Grand Marais the wave action has been restricted, for lack of supply of new material, to working over the old material brought there before the bar was established; and its effect has been doubtless to extend the size of the bay and render it shallow. Within the bay the crest of the living beach has an altitude of 5.5 feet and is twenty-three feet distant from the water. Parallel to this and sixty-five feet farther inland across an intervening hollow is an old beach, the crest of which is 6.1 feet above the lake. Behind

this is again a hollow, and beyond the ground rises in two low steps to culminate in a third distinct and bare beach-crest at a distance 105 feet from the second. The altitude of this third beach is 12.1 feet. This is again followed landward by a parallel hollow, and again the ground rises (all bare shingle and gravel) in two low steps, each about twenty-five feet broad, the higher of which is 17.5 feet at its edge. Neither of these steps is taken to mark a definite stage of the water. The upper of these steps grades into a gently sloping wave-cut terrace 260 feet wide and 29.1 feet high at its rear. Thus from the back of this terrace to the present shore there appears to have been no sudden drop in the level of the lake, but a gradual recession of the water. At this stage the waves were cutting a terrace out of a pre-existent embankment of shingle and gravel. As the water sank, the supply of drift from neighboring cliffs seems to have increased so that terrace-cutting gave way to terrace-building. The particular section selected for measurement shows the wave-built terrace at its narrowest part. Farther east it is many times broader.

Along the line of examination the cutting action which produced the terrace of the strand had eaten back into an embankment of shingle to the line of a beach of a former higher stage of the lake. For at the rear of the terrace a low sea-cliff of shingle rises with a slope of 28°, and this slope is nearly coincident with the front slope of a very distinct shingle beach with a hollow behind it, the crest of which is 43.6 feet above the lake. Above the level of this beach, the slope of the hill rises gently with an undulating profile, and presents a surface of gravel obscured by forest loam and shrubbery. In this vaguely undulating profile which was plotted to a large scale with great care, in the field, only two shore lines are distinctly registered, viz.: one at an elevation of 55.9 feet, in the form of a terrace twenty-six feet wide, and another at 113.5 feet, where the last of the gravel was observed.

Less than half a mile farther west, however, two still higher strand lines were observed and their altitudes measured. The lower of these is a terrace 127.3 feet high, which is well seen from a distance towards evening, but which is less apparent at close quarters. The higher is a distinct but not an extensive gravel terrace encircling low glaciated domes of rock at an elevation of 162.6 feet. This upper terrace is nearly on a level with the lower part of the bold bluff which overlooks Grand Marais on its southwest side. This bluff presents vertical walls from twenty to fifty feet high and was a sea-cliff when the water stood at the 162.6-foot level. On the east side of Grand Marais village a trail goes up over the hill. This was followed to the summit of the pass, about 750 feet above the lake, in search of higher strand lines. But, although the trail passes almost continuously over morainic accumulations, no trace of a shore line was observed at levels higher than that last recorded.

Kimball's creek. From Grand Marais eastward a low terrace, corresponding to the 29.1 feet terrace at Grand Marais, may be observed for several miles along the coast as far as Cow-tongue point. Higher traces of shore lines are doubtless present, but they are utterly obscured by the jungle. At the bottom of the bay below Cow-tongue point three terraces are observable from the lake, but only two of these could be located. The third eluded our search, although it must have been covered by us in our excursion in quest of it near Kimball's creek; and the second was difficult to locate with precision on account of the lack of contrast between its slope and that of a pre-existent slope of rock in which no cliff had been carved. This terrace has a measured minimum elevation of 80.1 feet, and its maximum is within two or three feet of this figure. It is evidently neither a wave-cut nor a wave-built terrace, but might be classed as a current-built terrace. Below this is a flat clearing on which stands a halfbreed's house. The flat is the first of the three terraces referred to. At its rear it is 28.5 feet high, and above it rises a steeply inclined sea-cliff carved out of the primary embankment, whose upper surface constitutes the second terrace. Farther along the shore this terrace is again seen about a mile below Fish-hook point, and again below the mouth of Brulé river, where it is being cut into by the wave-action so as to present the scarp of a sea-cliff rising above the existing shore.

Horseshoe bay. At the bottom of Horseshoe bay there is a very remarkable and striking series of three beautifully developed beaches. The bay, as its name implies, is not long proportionate to its width, but its shores converge towards the upper end, and the wave action has been exceedingly energetic in consequence of this rapid convergence. Vertical cliffs of massive gabbro in the vicinity of the bay, particularly on its west side, where they rise to an elevation of fifty feet, have supplied the material of which the beaches are constructed. There is also a sparing admixture of glacial erratics. The remarkable feature about the beaches is that there is no shingle or gravel, or any fine material whatever, in their composition. They are strictly boulder beaches, resembling ridges of cannon balls, although there are as many sub-angular boulders as rounded ones (see plate KK, figure 2). The crest of the lowest of these beaches is only twenty feet horizontally distant from the present shore line, and its crest is 11.9 feet above the lake. The crest is strikingly horizontal and curves parallel to the contour of the shore. It may be the storm beach of the present stage of the water, but the size of the boulders, which range on an average from six to twelve inches in diameter, suggest that the crest was built up when the water was somewhat higher than now. Behind this beach there is a slight depression, and behind this the second boulder beach rises to an elevation along its crest of 17.6 feet. The distance between the two beaches from crest to crest is about 100 feet. The boulders of which this beach is composed do not, on the average, vary much from twelve inches in diameter. This second beach is again followed by the usual parallel hollow, and behind this rises the third and most imposing beach of the three. The crest of the latter is 200 feet distant from that of the second beach and is 38.6 feet high. The front of this beach is not a simple slope, as is the case with the two lower beaches, but its profile shows a distinct step-like feature in its lower part, such as may be sometimes seen in clear water on the subaqueous slope of some of the living beaches of the lake. The component boulders of this beach are perceptibly larger than those of the lower beaches, the average diameter being over twelve inches. Many were measured which greatly exceeded this dimension. This beach was clearly developed

as a bar across the bay when the water formed the 38.6 foot beach, for behind the beach there is a broad expanse of marshy ground, much lower than the beach, which represents the lagoon formed by the establishment of the beach bar. At higher elevations of the surface of the water, Horseshoe bay would have been merged with the common expanse of the lake and the shore carried further inland than the range of our observations.

Double bay. A fine display of terrace topography, visible through the burnt and still standing timber, meets the view on entering Double bay. The present shore line is backed by a steep sea-cliff which is being carved out of an embankment which is probably fundamentally morainic, although modified in form by shore action of former high stages of the lake. Numerous boulders are worked out of the embankment and are strewn along the present shore, but it is largely also composed of clayey material. Stretching back from the brink of this sea-cliff is a nearly flat terrace, which is about a quarter of a mile broad, and which spans the entire breadth of the embayment. The rear of this terrace is about thirty-two feet above the lake. Above it rises a second sea-cliff followed by another broad terrace similar to the first, having an altitude at its rear which measured 85.8 feet. This second sea-cliff is not continuously distinct. Above it spreads out a broad, sloping plain, which varies in width according to the topography of the rocky slope which here begins to emerge through the superincumbent embankment. Along the line of section measured, this terrace is about a half mile wide and abuts upon a rocky slope; the line of abutment is horizontal, and although no well-marked sea-cliff has been developed, owing to the resistant character of the rock, it may with great probability be taken to mark approximately a shore line. Its elevation, as measured, is 160.5 feet. On top of this rocky ridge at an elevation of 278.9 feet, and at a distance inland of about a tenth of a mile from the rear of the last mentioned terrace, was found a distinct gravel bar surrounding low, rocky knolls and spanning the gaps between them. To the northeastward this beach appears to merge into a terrace which abuts upon the precipitous flanks of a spur of Farquhar's knob. The rear of this terrace would be a few feet higher than the figures given for the elevation of the gravel bar, but its precise elevation was not determined.

Grand Portage. It was hoped from a distant inspection of the topography of the pass through the hills at Grand Portage, from its being fairly free from timber, and from its gentle grade, which renders the country accessible for some miles from shore within moderate limits of elevation, that the registration of the ancient strand lines of lake Superior would at this place be fuller than usual. This hope was, however, not fulfilled, and only a few of the strand lines were satisfactorily located by carrying a line of levels along the portage trail. From the nature of the embayment in the hills it is evident at a glance that at the higher stages of the water Grand Portage bay must have extended several miles inland and have had a somewhat irregular shore contour with sharp indentations, particularly on its west side. From the precipitous character of the bluffs or promontories, which limit the embayment on either side, it is presumed that very little of the general shore drift found a lodgment in the bay, and whatever embankments may have accumulated would be of local derivation. The fact that the general shore drift did not find its way into the bay at the higher stages of the lake, either around mount Josephine on the east, or the bold precipices which rise on the west of the embayment, is evidenced by the absence of such drift on the wave-cut terraces, which contour these precipitous slopes on either hand, as will be noted later. In spite of this exclusion of the general shore drift, there is evidence that, at probably all recorded stages of the water, the water was in the middle parts of the bay as it is now, always shallow, and that waves, although very effective on the neighboring steep slopes where the water was deep, left comparatively feeble traces of their action on the successive shores at the head of the bay. The conditions which have favored an excessive accumulation of local detritus in the bay and rendered it shallow from the highest stages of the lake down to the present, are: (1) The presence of a massive morainic ridge crossing the valley about four miles north of the village, and (2) A small stream cutting through it, which has built up a succession of sloping delta plains, each of which has been cut through in turn as the level of the lake dropped. The higher and older delta plains appear to be much more extensive than the later, and it is a possible case that at the time of their building the stream flowed from beneath ice still lingering behind the moraine in the upper part of the valley. The highest delta forms a very distinct broad plain which has been terraced by the stream, but which cannot be clearly separated at its rear from the present front slope of the moraine. Half a mile or more in front of the moraine there projects through the plain a rocky, glaciated dome a few hundred feet in diameter. The abutment of the plain upon the steep slopes of this island-like mass of bare rock is very sharp. An inspection of the surface of the rock, which is uneven in detail on top, warrants the belief that it was not submerged at the time of the formation of the plain which encircles it, and that it was, therefore, but little above the level of the water which conditioned the slope of the plain. The elevation of the plain at this point was measured at 339.7 feet.

A higher terrace was also observed abutting on a rocky slope at an elevation of 458 feet, but the brushy character of country obscured its relation to that just mentioned and it could not be determined to be distinct from it.

Further down the valley on a lower delta slope are two low, beach-like ridges, one at 254.7 feet, and another at 231.8 feet, which appear to have been barriers thrown up by the breakers in a shallow bay at some distance from the shore and similar to the barrier which is now forming in Grand Portage bay. On a still lower delta plain and much nearer the lake is still another low barrier ridge which has an elevation of 103.5 feet. The church of the village stands on a terrace which, at its rear, at the foot of a low and worn-down cliff carved out of delta material, is 74.7 feet high. Immediately to the lakeward side of the church the ground drops steeply to the level of the terrace on which the village is built. This drop represents a sea-cliff which is one of the most striking shore features of Grand Portage. The terrace which extends out from its base is 37.9 feet above the lake. There is still a lower terrace, the rear of which is about 8.6 feet above the lake. The present bay is shal-

low out as far as Grand Portage island, so that the waves break before reaching shore; and one of the results of this is the development of a subaqueous ridge or barrier parallel with the shore line. Boats drawing over a foot of water may ground on this barrier, but between it and the shore the water is deeper. The barrier, as yet, appears nowhere above the surface of the lake and probably it will never so develop into a barrier beach, but always remain subaqueous, since heavy storm waves necessary for the throwing up of the initial subaerial ridge cannot reach this line on account of the lakeward shoal.

Mount Josephine. The south side of mount Josephine presents a succession of strand lines, most of which are exceptionally well defined. The mountain is a ridge 703 feet high and consists of a great dike of gabbro or diabase, to both of the steep flanks of which a selvage of southerly dipping slates and quartzyte of the Animikie is still adhering up to varying elevations. The extremity of the ridge juts out into the lake as a sharp point which forms the eastern limit of Grand Portage bay and is known as Hat point. The most striking and most heavily scored of the strand lines is a wave-cut terrace which contours the side of the ridge at an elevation of 509.5 feet and sweeps around in a beautifully shaped curve where the ridge abuts upon the main mass of rock from which it is a spur. The timber has been burnt over a portion of the hillside so that the character of the terrace, as a heavily cut shelf, perfectly horizontal, projected against the side of the hill, attracts the eye from a long way off, and excites the curiosity of even the casual observer as a peculiar feature of the landscape. At close quarters the terrace was found to be about 100 feet wide, to have a gentle lakeward slope for this distance, and then to drop away into a steep declivity of the hillside. At its rear rises a steep cliff which is partly the side of the great dike, partly the indurated slates adhering to the dike, and partly a wall of the dike rock, farther in than its original side wall, which has been established by the cutting action at the level of the terrace. The terrace is strewn with great blocks which have fallen from the vertical cliff, and at one place a considerable talus has accumulated in great part since the wave action ceased. There is a considerable proportion of glacial drift over the lower flanks of the ridge, and this seems to have extended up to the summit of the ridge, since there are some northern erratics strewn over the surface of the terrace. It is possible that the terrace may, in part, particularly at its northern end, be cut out of a morainic dump. The summit of mount Josephine is heavily glaciated. A small portion of beach shingle and gravel is strewn over the surface of the terrace. The possibility of the terrace being a feature of differential degradation was critically considered on the ground, but all the evidence observed made clearly for its wave-wrought origin. The facts that the strata dip southerly while the rear of the terrace is horizontal, that the slope of the terrace is outward and independent of the dip, and that the terrace character is maintained where it swings in the curve of the —— away from the line of the dike, indicate at once that its form and situation are not conditioned by the structure of the rocks. The terrace is further interesting as yielding to accurate measurement figures for its altitude, which are identical with those obtained for the equally well-defined strand line at Hardy's schoolhouse in East Duluth.

This terrace, although the most pronounced of the dents in the west side of mount Josephine, is not the highest. There are two higher and presumably older terraces, neither of which is so extensive along the hillside nor so wide. Both of these are much alike in their general character and in the measure of their extent, and they rise one above the other. They are continuous for only a few hundred yards, and both vary from about thirty to fifty feet in width. Both are backed by a sea-cliff and both are strewn with blocks of rocks derived from it and from drift accumulations. These terraces are respectively 587.2 feet and 607.3 feet above the lake. One of them is a prominent feature of the hillside as a distinct horizontal shelf, visible at long distance; the other is not so apparent, owing, doubtless, to the thickened shrubbery. It is suggested, in explanation of their short extent, that they lie in a slight embayment on the side of this ridge and so somewhat protected; while their continuation on the more salient portions of the ridge has been undermined and cut away by the same wave action which resulted in the development of the broader terrace at 509 feet. These two terraces, at 587 feet and 607 feet, are remarkable for being the highest strand lines which have thus far been observed on the coast of lake Superior.

Lower on the same slope of mount Josephine are two other sharply scored but narrow terraces, which lie well within the unburnt timber, and which are therefore not apparent at a distance. The first of them, in descending order, is at an elevation of 313.5 feet and the second at 226.1 feet. Both are readily observable on the trail which crosses mount Josephine from Grand Portage to Wauswaugoning bay, and both appear to be cut out of the accumulation of drift which here mantles the rocky base of the ridge. Still further down, at the base of the hill, is a boulder beach, the crest of which is forty-three feet above the lake; and between this and the shore there is again a drop in the general slope to an even terrace which is 19.9 feet high at its rear, and which extends for less than 100 yards to the brink of the sea-cliff of the present shore. This last sea-cliff has a hight of thirteen feet.

Wauswaugoning bay. Wauswaugoning bay is limited on the southwest side by Hat point and on the northeast by the base of Pigeon point. The shore along the side of Hat point is a precipitous cliff without a beach or visible shelf at its base, and the water is deep. This line of high cliff, rising in places to a hight of 800 feet, is continuous around the embayment, but leaves the shore line about half way from the extremity of the point and sweeps round to the vicinity of Pigeon falls, roughly parallel to the shore, but usually several hundred yards distant from it. At the base of Pigeon point the ground is low, and at higher stages of the water Pigeon point was either an island or was completely submerged, so that a portion of the sediment of Pigeon river then found its way into Wauswaugoning bay. But as Pigeon river is a new stream, being a succession of cataracts and stretches of still water, the sediment is small in quantity and very fine, so that it supplied practically no material which would remain in the zone of shore drift on a wave-beaten shore. Its sediments have taken the

form of a delta at the head of Pigeon bay where protected from wave action. The Pigeon river is clearly a very recent drainage and it seems probable that the ancient outlet was into Grand Portage bay. This dearth of stream detritus has characterized the shores of Wauswaugoning bay at all stages of lake Superior, there being no other stream cutting through or tumbling over the cliffs which rise around it. In this respect the bay presents a marked contrast to the neighboring bay at Grand Portage with its heavy deltas. The contrast between the two bays is perhaps best seen in the character of the strand line registrations. The higher stages of the lake were not strongly registered at the head of Grand Portage bay because of the lack of contrast between the subaerial and subaqueous slopes of the delta. At the head of Wauswaugoning bay the water line of the higher stage was not registered at all, because the shore was along the face of vertical cliffs of pre-lacustrine origin. As the lake subsided the water surface reached the talus of the cliffs, and terrace lines were doubtless carved. But in the vicinity of the cliffs the growth of the talus since the water subsided has rendered them unrecognizable; and it is only when we come to comparatively low stages of the lake, where, on the gentler slopes of the talus, conditions have been favorable for the carrying of a bar across the head of the bay, that permanent strand lines have been established. These bars form two magnificent beach embankments with lagoon hollow behind and undulatory slope in front. They are composed entirely of coarse shingle of quartzyte and hard siliceous slate which mostly weather red. The vegetation has been burnt off and the crests are remarkably sharp and continuously horizontal lines, which by their color and distinctness give a striking character to the landscape. The upper of these two beaches is 76.5 feet above the lake (see plate JJ, figure 1), and the lower 43.7 feet.

Near Birch island. Outside of Wauswaugoning bay on the south side of Pigeon point and about half a mile east of Birch island there is a fine display of storm beaches. The material of which they are built is the detritus of the reddish Animikie quartzyte which is the prevalent rock on this part of the coast. The shore is well exposed to southerly winds. The beaches, although well developed, are here only found at comparatively low altitudes, there being no high slopes upon which embankments of higher stages of the lake could be lodged. Three distinct beach crests rise one above the other, all having the same general character. The first of these is within reach of the waves of the present stage of the lake, and is possibly the living storm beach in process of growth, or having attained its maximum growth. Its crest is sharp and uniformly level at 13.6 feet above still water. About 150 feet from this crest rises the second beach equally sharp and distinct, with an elevation of 17.4. On the front slope of this beach is a subordinate shelf-like feature. There is no perceptible depression in the 150 feet of space between the two beach lines. The third beach crest is about 100 feet behind the second, and there is a slight depression between the two. There is a depression behind the third beach, *i. e.*, between it and the rocky slope upon which it has been banked up. The third beach has an elevation of twenty-one feet. All three beaches are absolutely devoid of soil or fine material of any kind. There is no blown sand to obscure their characters as perfect wave-built embankments of shingle and gravel spanning the bay between two rocky ridges.

Pigeon point. From the abandoned ranch at the mouth of Pigeon river a trail crosses Pigeon point to the shore on the south side. This trail is transverse to the trend of the rocks, and between the two main ridges is an embayment which opens to the southeast on the south side of the point. The trail in crossing this embayment follows the crest of a shingle beach which spans it. The total length of the beach is something less than one-eighth of a mile, there is no breach in it, and behind it is a well-defined lagoon hollow. The crest of the beach was found to have an elevation of 75.6 feet. On the front of the embankment which culminates in this beach a second beach has been developed at an altitude of 56.6 feet. It is probable that several other beaches lie between this and the shore, but the interval is heavily timbered and definite results are scarcely obtainable.

Pigeon river. At the mouth of Pigeon river, on the Canadian side, there are three fairly distinct traces of shore action. They are found on the south side of the point of land which separates the canon of the Pigeon from Pigeon bay. The highest is of the nature of a short gravel bar, connecting two projecting masses of rock. It is about one foot lower in its middle than at the sides where it abuts upon the rock. Its elevation at the latter place was found to be 134.3 feet. The fine character of the gravel (mostly of slate) and the low curvature of the bar indicate development under sheltered conditions, such as the local topography would suggest. On the lower flanks of the hillside are two distinct terraces, one at 60.8 feet and another at 18.2 feet, both of which are probably rather to be strictly interpreted as stream terraces of the Pigeon, but, being at its mouth and below rapid water, they represent very closely the stages of the lake at which they were developed.

MATERIAL RESOURCES.

There is a large quantity of timber, both hard and soft wood, standing in this county, and this will be of great value when the district is better settled. At present little can be done with the timber, for most of the streams, especially in their lower courses, have many rapids and falls. The value of the land for agricultural purposes has already been spoken of (page 320).

The iron ore thus far discovered in this county, as described in the chapters on the Akeley Lake and Gunflint Lake plates, while in large amounts, still cannot be

profitably mined with the present prices of ore. With better prices, or the establishment of blast furnaces on lake Superior, this ore, which is in large quantity, might be mined with profit. There are large bodies of titaniferous magnetite associated with the gabbro, which will be of value when an economical process of smelting titaniferous ores is in operation in this county. Nickel ore is found in small amount in the gabbro, and many important finds of this ore have been reported, but as yet none of them have been substantiated. By this it is not intended to state that nickel ore of sufficient richness to pay for working does not exist in the county, but only that at present such ore does not seem to have been found. The conditions seem to be favorable, and the future may show that it exists in paying quantities. Silver and copper have also been found in small amount, the former in the Animikie and the latter in the Keweenawan rocks, but neither metal is known in large amounts. The conditions for the discovery of silver-bearing veins in this county are favorable, as the geological structure of the northern part of the district is the same as that of the adjoining silver district of Ontario. The same can be said regarding copper, for geologically the conditions are favorable, but as yet no large deposits of this metal have been found.

Water-powers. Throughout the county are numerous streams which have considerable fall in short distances. This is especially true of the last few miles of the lower courses of the streams flowing into lake Superior. These streams often descend several hundred feet in a few miles from the lake, and, as the country becomes settled, these natural water powers can be easily utilized. The lakes of the county, as a rule, have narrow, rapid streams flowing from them. By a dam at the outlet of one of these lakes the lake level can be raised a few feet, thus forming a mill pond of large size.

GEOLOGICAL MAP.

The boundaries of the Animikie and Archean rocks are regarded as accurately located. Not so much can be said of the boundaries of the different parts of the Keweenawan, because (1) of the difficulty of separating the Cabotian and Manitou parts of this series in the southern part of the county, and (2) because the interior of the county has not been carefully explored. In mapping the parts of the Keweenewan on the lake Superior shore, the results obtained by the state geologist have been followed, while back from the lake shore notes of different parties of the survey have been used, and a map by Dr. A. H. Elftman * has been followed in many particulars.

Over a considerable portion of the county accurate topographic data are lacking, but in the northern part of the county and southward from T. 64-1 W. to Grand Marais, the data are good and were obtained by leveling and aneroid measurements.†

* *Amer. Geol.*, vol. xxii, pl. 7.

† This topographic work was done in 1893 by a party of the survey under the charge of Dr. C. P. BERKEY (see his report, *Twenty-second Annual Report*, pp. 134-140), the leveling being done by Messrs. L. A. OGAARD and A. N. WINCHELL.

ROCK SAMPLES.

The following rock samples, illustrating the rocks of Cook county, have been collected by the survey:*

N. H. Winchell's series: Nos. 161–321; 535–553; 603–627; 642–737; 767–796; 799, 800; 1070–1072; 1088–1092; 1264–1364; 1379–1384; 1772–1785; 1807–1906; 2044–2077.

A. Winchell's series: Nos. 358; 570–886.

H. V. Winchell's series: Nos. 433-462.

U. S. Grant's series: Nos. 6–67; 170–244; 645–689; 701–710; 712–726; 790, 791; 821-839; 847–849; 851, 852; 855–893; 894–909; 929–1008C.

A. H. Elftman's series: Nos. 292–350; 426–571; 638–696.

* This list includes some samples from Canadian territory immediately adjacent to the northern boundary of the county, as such samples have an important connection with the study of the geology of this county.

CHAPTER XIII.

THE GEOLOGY OF THE POKEGAMA LAKE PLATE.*

By U. S. GRANT.

Situation and area. The district here described lies in the southern part of Itasca county, and includes Ts. 54–26, 54–27, 55–26 and 55–27, all west of the Fourth principal meridian. It is rectangular in outline, being twelve miles long (north and south) and nine and a third miles wide (east and west), and thus contains 112 square miles.

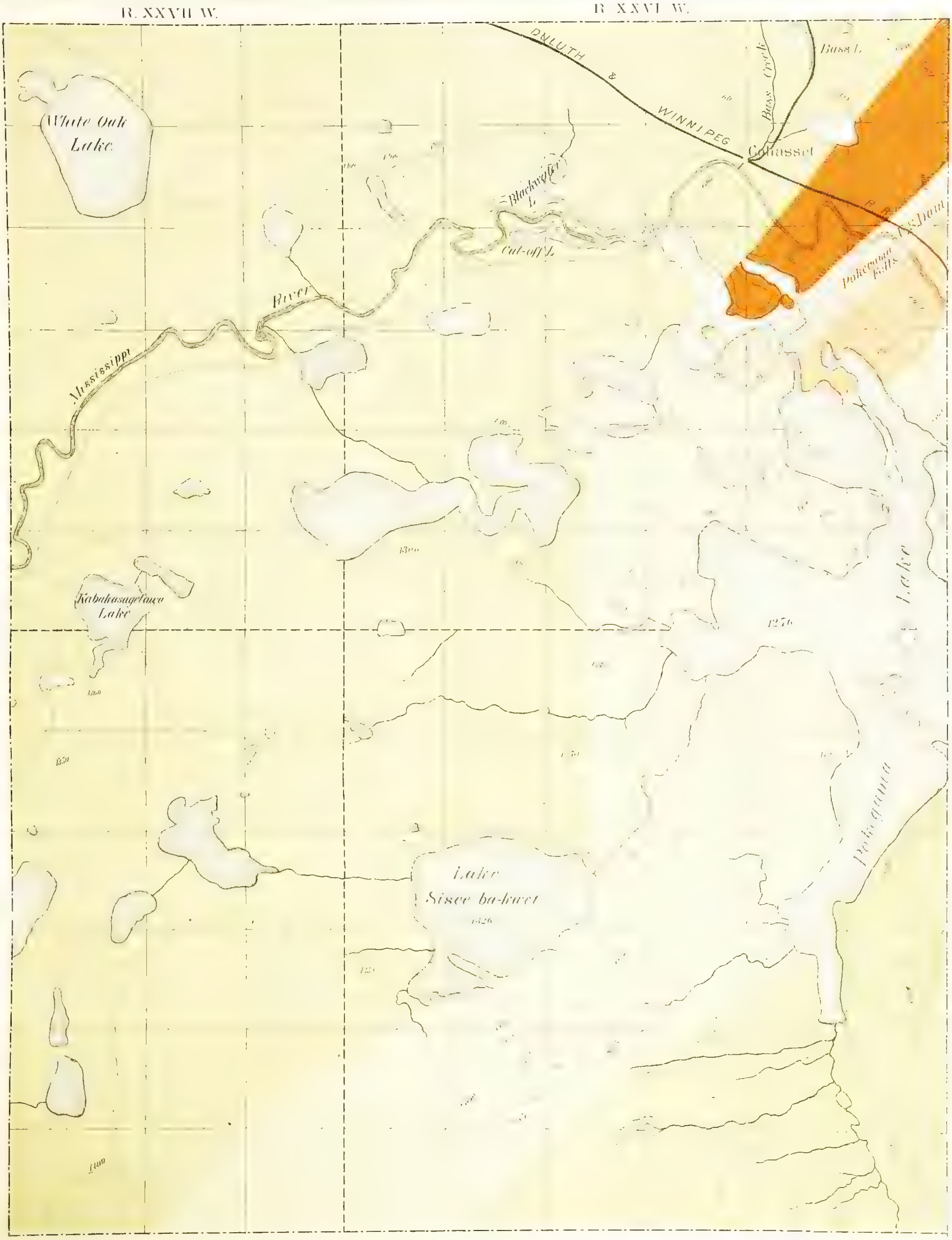
SURFACE FEATURES.

The surface is flat to gently undulating in general, being covered with deposits of till and modified drift, while in some places, as shown on the map, the surface becomes knolly or hilly and the drift is morainic in character. By far the most pronounced ridge is that lying southwest of Pokegama lake in secs. 22, 27, 28 and 29 of T. 54–26 W. The highest point reached by this ridge is in the north half of sec. 28 and is 1,617 feet above the sea level or 341 feet above Pokegama lake. This point is probably the highest between the west line of St. Louis county and the district southwest from Itasca lake. Lakes are quite abundant, Pokegama lake, lying on the eastern side of the plate, being the largest. The district is drained by the Mississippi river, which flows eastward through its northern half. Rock exposures are quite scarce; in fact the only ones we have record of are in the vicinity of Pokegama falls and some reported ones to the southwest of that place. The drift thus practically covers all the bed rock to a depth which perhaps averages fifty feet, or even more.

GEOLOGICAL STRUCTURE.

Granitic rocks. On the map (plate 70) a belt of granite is shown extending southwestwardly for a distance of three miles from the northeast corner of the plate. The survey has no records of granite outcrops in this area, but, from the existence of granite just to the northeast and from its known relations to the Pokegama quartzyte, we feel reasonably sure that the granitic rocks underlie the drift in the

*The sources of information for this chapter are practically the same as for the chapter on Itasca county, excepting the report of A. C. Lawson and that of H. V. Winchell and U. S. Grant. (See first foot note under the description of that county.) The writer is not personally acquainted with the district included in this plate.



GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA

POKEGAMA LAKE PLATE

COMPILED BY U.S. GRANT.

Roads and Trails
Railroads
Fifty foot contours
Hundred foot contours

Explanation

area represented. The southern, or southeastern, limit of the granitic rocks beyond the area colored on the map is thought to run from near the centre of sec. 22, T. 55-26 W., southwest, passing near the southwest corner of this section and a little north of the northwest corner of sec. 28, T. 55-26 W., and leaving this township in section 31. Beyond this it is supposed to pursue the same general direction, at least for several miles. All that part of the plate northwest of this line seems, quite probably, to be underlain by granitic rocks. These rocks, as stated under the chapter on Itasca county, are regarded, in part at least, as Archean eruptives of an age later than the Lower Keewatin and possibly later than the Upper Keewatin.

The Animikie. This formation is represented in this plate by the lower or quartzyte member (Pokegama quartzyte) and the taconyte or iron-bearing member.

(1). Pokegama quartzyte. This occupies a narrow belt, about half a mile in width, just to the southeast of the granitic rocks already mentioned, and it overlies the granite unconformably. The quartzyte probably extends, under the drift, southwest for a number of miles, lying along the southeastern limit of the granitic rocks, which limit has already been roughly indicated. Indeed, quartzyte has been reported to outcrop in three or four places to the southwest of Pokegama falls, but we have been unable to visit the localities to verify the reports, still we regard them as trustworthy, and, moreover, the reported outcrops are in the line of strike of the Animikie and thus occur where we should expect to find quartzyte.

At Pokegama falls this rock appears in outcrop and causes the falls. Below the falls the dip is 15° towards S. 8° W.; above the falls, 15° S. 8° E. The rock is in general a rather vitreous quartzyte which has been more or less iron stained. The original color as shown by the interior is a greenish gray, and the coloration has proceeded along exposed surfaces, cracks and joint planes, often producing a mottled rock which is gray, greenish, brownish or reddish in color. At times it is more or less crumbling, especially where stained by iron. A fine-grained conglomerate is seen in places, and some flat pieces of a red, shaly material, sometimes two inches or more across, are included in the quartzyte. This material reminds one of the pipestone associated with the Sioux quartzyte in the southwestern part of the state. These red pieces were probably fragments of Keewatin slate or shale included in the quartzyte when it was being deposited, and they have since become iron-stained and soft. If this is true, we may expect Keewatin rocks not far removed from this locality. Such rocks are known to occur underlying the quartzyte in certain parts of St. Louis county, but we do not know of their actual occurrence in such a position in Itasca county. Another feature of the quartzyte is its spottedness. Roughly circular areas, of all sizes up to an inch or more across, are sometimes common. These areas are reddish or brownish in color, and are rich in iron. They

appear more granular than the rest of the rock, probably because the hard siliceous cement of the rock has been dissolved away, and partly or wholly replaced by the softer iron ore. An examination of this quartzyte under the microscope shows that the rock originally consisted of rounded quartz grains, *i. e.* the rock was a sandstone, and that since its deposition silica has been deposited among and around the sand grains, cementing them together. When this process is completed the rock has a vitreous rather than a granular aspect. The silica thus deposited is completely crystallized and many of the original sand grains show crystalline enlargements.

About one-sixth of a mile above Pokegama falls and on the west side of the river is a bluff of the same quartzyte rising twenty-five feet above the water. The dip here is 8° towards S. 22° E. Before Pokegama lake was raised by the government dam the quartzyte appeared in a low outcrop in N. W. ¼ sec. 23, T. 55–26 W., and formed a small rapid at the outlet of Pokegama lake. This outcrop is now entirely covered by water. The quartzyte has also been reported on the Little Boy river in Cass county, also about eight miles southwest of Pokegama falls and in sec. 31, T. 55–26 W., or sec. 6, T. 54–26 W. All of these localities are in the general direction of the strike of the Animikie, and they tend to confirm the idea that the Animikie rocks, both the quartzyte and the iron-bearing member, extend for a considerable distance southwest from Pokegama falls.

(2). Taconyte or iron-bearing member. These rocks are not known to the survey in the area included in this plate, but there is no reason to doubt that they exist immediately to the southeast of the quartzyte belt along its known and probable extent. There are prospects that bodies of iron ore will be found in the belt of iron-bearing rocks represented on the map, as well as to the southwest, but the covering of drift may be so thick that the discovery of these ore bodies will be a rather expensive process.

The Cretaceous. No strata of this age have been actually found in place in this district, although they are known, in three places, at least, along the southern slope of the Mesabi iron range a few miles to the east, and it is quite probable that such strata exist within the area of this sheet. Indeed, there are reasons for regarding the high ridge in secs. 22, 27, 28 and 29, T. 54–26 W., as composed of a mass of Cretaceous rocks covered by only a small thickness of drift. The oval hill in secs. 22 and 23, T. 55–26 W., may also be of similar character. The high ridge just mentioned bears, especially along its northern face, morainic accumulations, but its summit and southern side do not appear to be of this character. The surface is here apparently of blue clay, and in shallow cuts on logging roads fragments of what seem to be Cretaceous shale are found.

GEOLOGICAL MAP.

On the map only the areas where we are reasonably sure that the granitic rocks and the two divisions of the Animikie occur are thus indicated. The line between the granitic rocks and the quartzyte, as well as that between the latter and the iron-bearing rocks, is, we feel, quite accurately located. But an attempt to mark the exact location of these lines towards the southwest would, with our present knowledge, most likely prove unsuccessful. The most probable location of the limits of these formations in this direction has already been indicated. The drift is mapped as morainic and otherwise, the areas of non-morainic till, modified drift and a little alluvium along the Mississippi river being represented by one color. The contour lines were obtained with the aid of an aneroid barometer and may be regarded as approximately correct.

ROCK SAMPLES.

The following rock samples were collected within the area of this plate:

N. H. Winchell's series: No. 1521.
H. V. Winchell's series: Nos. 256-259; 284, 285.

CHAPTER XIV.

THE GEOLOGY OF THE GRAND RAPIDS PLATE.*

By U. S. GRANT.

Situation and area. The district here described lies in the southern part of Itasca county and includes Ts. 55–24, 55–25, 56–24 and 56–25, all west of the Fourth principal meridian. It is two townships or twelve miles square and thus contains 144 square miles. It includes the Mesabi iron range between the Pokegama Lake plate (No. 70) on the west, and the Swan Lake plate (No. 72) on the east.

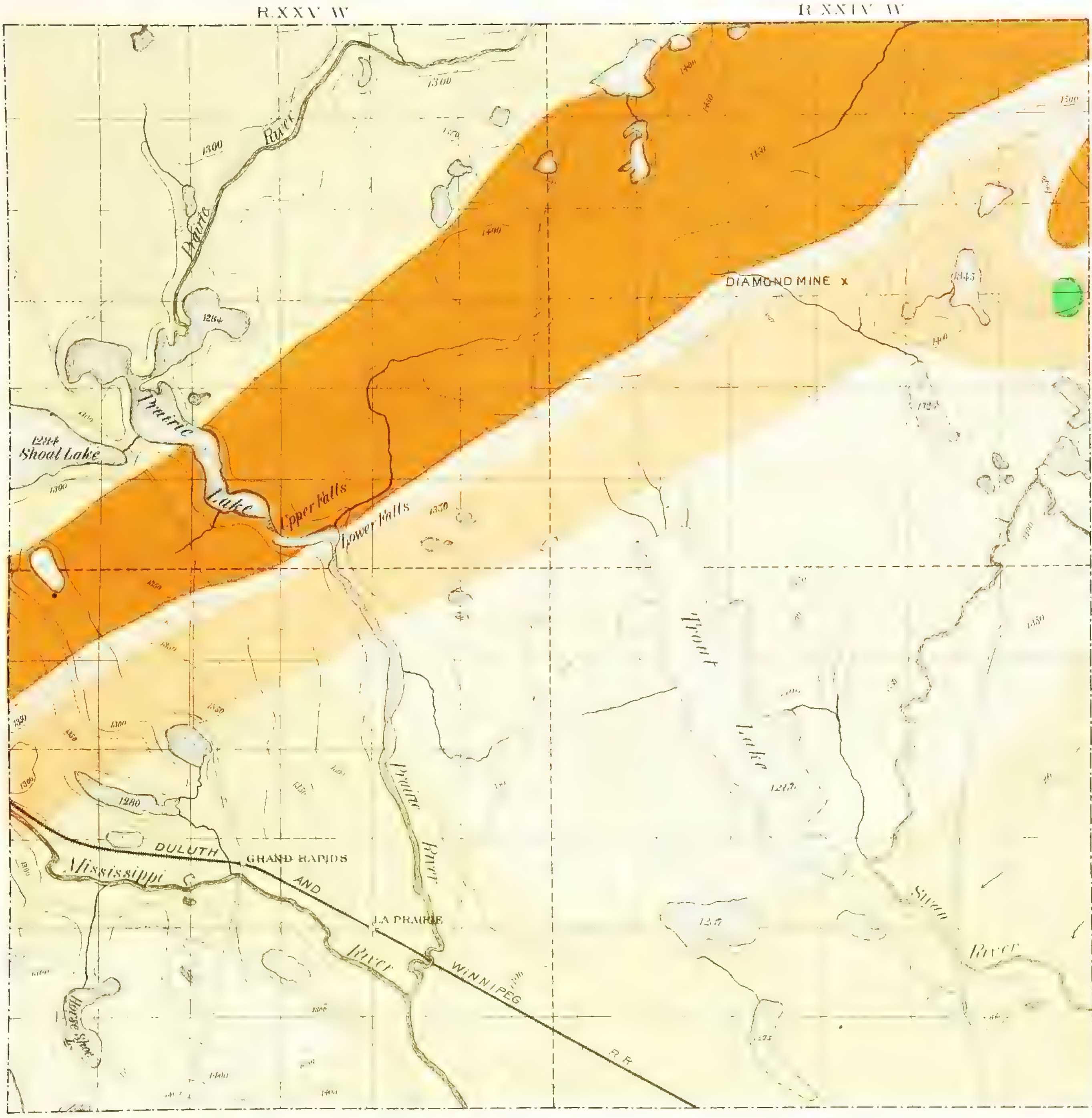
SURFACE FEATURES.

The surface is in general undulating, but in the south half of T. 55–24 W. it is nearly flat, and, as shown on the map, a morainic belt lies along the south side of the Mesabi range. This morainic belt is quite pronounced in T. 56–24 W., along part of the area which is marked as underlain by the iron-bearing rocks. There are no great differences in relief, but a few hills, as west of Trout lake and in the north half of sec. 21, T. 56–24 W., rise about 200 feet above the surrounding country. The lowest part of the district, along its southern side from the Mississippi river eastward, is something over 1,250 feet above the sea, and the highest land is in the northeast corner where the Giant's range begins to develop and where altitudes of over 1,500 feet are reached. The district is drained by the Mississippi river and two of its tributaries, Prairie and Swan rivers. Rock exposures are more common than in the Pokegama Lake plate, and there are a number of test pits in the area underlain by the iron-bearing rocks.

GEOLOGICAL STRUCTURE.

Granitic rocks. The southeastern limit of these rocks enters the plate on the west near the centre of the west side of sec. 7, T. 55–25 W., and runs in a northeasterly direction, leaving the plate near the centre of the east side of sec. 1, T. 56–24 W. These rocks probably underlie all of the area of the plate to the northwest of this limit, and they outcrop in a number of localities within the area colored as granitic rocks on the map.

* The sources of information for this chapter are practically the same as for the chapter on Itasca county, excepting the report of A. C. Lawson and that of H. V. Winchell and U. S. Grant. (See first foot note under the description of that county.) We are especially indebted to Hon. S. P. Snider, of Minneapolis, for information concerning the location of the formations in certain parts of this plate. The writer is not personally acquainted with this district.



GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.

GRAND RAPIDS PLATE

COMPILED BY U. S. GRANT

Explanation

Glacial | *Till flat or undulating and modified drift*
| *Till knolly and hilly terminal moraine*
Cretaceous | *Shales conglomerate etc.*
Animikie | *Taconyte or iron bearing member*
| *Pokegama quartzyte*
Archean | *Granitic rocks*
Geological lines

Roads
Railroads
Fifty foot contours
Hundred foot contours

At the Upper falls of Prairie river (near the centre of the E. ½ E. ½ sec. 33, T. 56–25 W.) these granitic rocks occur in extensive exposures. The river here runs through a narrow, rocky channel, only twenty-five feet wide in one place, with sides rising thirty to forty feet above the water. At the foot of the rapid the rock is a fine-grained, gray, gneissoid granite. It appears in nearly horizontal layers, and varies in color from white to reddish. It changes in ascending the rapid, becoming coarser in grain and containing more biotite and feldspar. Some of the feldspar is quite red. Veins of coarse, reddish granite, of all sizes up to those six inches across, cut the country rock. To the northeast of the falls rocks of the same general character as occur at the falls are found in several outcrops. In one place, at about half a mile from the falls, an outcrop of dark greenish dioritic rock occurs in close proximity to the granite, but its relation to that rock is not known. Such masses of hornblendic rock are found farther east in this granite area and are shown to be enclosures of foreign rock in the granite. This dioritic outcrop may be of a similar nature, or it is possible that it represents a dike cutting the granite.

Near the southeast corner of sec. 27, T. 56–25 W., the granite is slightly porphyritic with feldspar. Numerous other outcrops occur to the northeast, especially in secs. 4, 9 and 19, T. 56–24 W.

The Animikie. As in the Pokegama Lake plate the Animikie is represented by the quartzyte (Pokegama) and the taconyte or iron-bearing member.

(1). Pokegama quartzyte. This occupies the narrow belt between the granitic rocks on the northwest and the taconyte on the southeast. The quartzyte occurs in outcrop at the Lower falls of Prairie river, in S. E. ¼ sec. 34, T. 56–25 W. In general the rock is the same as at Pokegama falls, but about half way up the rapid is a fine conglomerate, the pebbles being largely of quartz, although pebbles of a fine-grained, slaty rock are not uncommon. In one place the quartzyte is spotted with white areas which, except in color, do not appear different from the rest of the rock, which is of a brownish shade. The contact between the quartzyte and the granite was not found, although searched for considerably.

Near the dam at the foot of Prairie lake, just north of an exposure of quartzyte, is a narrow belt on which are thickly strewn many small boulders of greenish gray sandstone, but no exposure of this rock is known. The boulders split easily into flags and are composed of a somewhat micaceous sandstone. The belt in which these boulders lie is some four or five rods in width. Passing across this belt towards the quartzyte the sandstone boulders are quite abruptly replaced by boulders of quartzyte, which occupy a belt perhaps ten or fifteen rods wide, beyond which the quartzyte occurs in place. It seems quite probable that the sandstone occurs in place under the area covered by the boulders of this rock, and thus that the sandstone

underlies the quartzyte. The accompanying figure shows a north and south section at this locality, the granite being on the north and underlying the quartzyte unconformably.

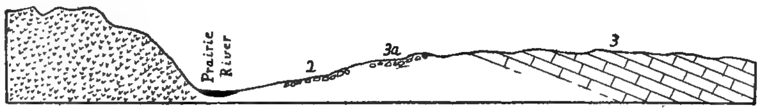


FIG. 61. SECTION, NORTH AND SOUTH, NEAR THE LOWER FALLS OF PRAIRIE RIVER.

1–Granite. 2–Sandstone boulders.
3a–Quartzyte boulders. 3–Quartzyte in place.

The quartzyte at the Lower falls dips in the main toward the south-southeast at an angle averaging about 10°, and it undulates in one or two gentle folds. Along the top of one of the anticlinals can be seen a distinct fracture, opening upwards as the crest runs across the river.

Quartzyte occurs in several outcrops in the vicinity of the lower falls and also to the northwest-northeast, especially in sec. 16, T. 56–24 W., where outcrops occur near the southwest corner of the section, and a ridge exists near the centre of the section. To the southwest of the falls the quartzyte occurs, notably in sec. 5, T. 55–25 W., near the centre of the section, and on its east side about a third of a mile from the northeast corner.

It will be noticed on the map that the Animikie rocks are shown to bend to the south near the northeast corner of T. 56–24 W., and then to bend northeast again in section 13 of the same township. By comparing this map with the Swan Lake plate (plate 72) it will be seen that, if the quartzyte belt in T. 56–24 W. was continued in the direction of its strike, it would pass about two miles northwest of the quartzyte as it actually exists in T. 56–23 W. Some irregularity occurs here, as is indicated by the outcrops, and the rock found in test pits, and as is represented on the map. In the immediate vicinity of this irregularity we have records of the granite, quartzyte and taconyte, as follows:

Granite. Near centre of sec. 10; near south quarter post of sec. 2, T. 56-24 W.; near southwest corner of sec. 7, T. 56-23 W.

Quartzyte. A little south of the centre of section 15; a little southeast of the centre of N. W. ¼ sec. 11; a little west of the east quarter post of sec. 1; near centre of sec. 13; N. ½ S. W. ¼ S. E. ¼ sec. 13, T. 56-24 W.; ridge west of centre of sec. 18, T. 56-23 W.

Taconyte. Diamond mine (S. E. ¼ S. W. ¼ sec. 15) S. W. ¼ S. W. ¼ sec. 14; many localities in S. ½ S. ½ sec. 13, T. 56-24 W.

From the data at hand it would be as easy to assume a fault as the bend in the strata represented on the map. If a fault exists, the fault plane is probably nearly vertical, and it runs from near the east quarter post of sec. 1, T. 56–24 W., south-southwest into the west half of section 13. This irregularity in the strike of the Animikie has its analogue near Virginia (see the Virginia plate No. 75). To the writer it appears that these irregularities can best be explained by assuming that the

southward extending tongue of Archean rocks was originally covered by an anticline of Animikie rocks which have been eroded, revealing the underlying Archean, which was bowed up under the arch of Animikie strata. At any rate, there is evidence that the Animikie, in addition to its gentle south-southeastwardly dip and small undulations whose axes run at right angles to this direction, also has gentle folds, resulting from a compression acting in an east-southeast and west-northwest direction. The three irregularities mentioned above may be assumed to be along the axes of the more pronounced folds resulting from this force.

It is also possible that these southward extending tongues of Archean rocks represent ridges in the surface on which the Animikie was deposited. There seem to be reasons for assuming that the Archean rocks were reduced practically to a base level before the Animikie was deposited, and the general straight limit of the Animikie rocks on the north and the character of the deposits, lead one to think that sharp ridges did not exist in the surface on which the Animikie was laid down.

It is assumed, from the evidence at hand, that the tongue of granite running into the N. E. ¼ sec. 13, T. 56–24 W., has the quartzyte dipping away from it on all sides except the northeast, while the quartzyte in sections 1 and 12 forms a syncline.

(2). Taconyte or iron-bearing member. This lies just to the south of the quartzyte belt and its southern limit is unknown on account of the heavy covering of drift. It outcrops just to the south of the quartzyte at the Lower falls of Prairie river. The thickness of this taconyte member here exposed probably does not exceed six feet and it rests directly on the quartzyte. The taconyte here varies considerably, being in general a reddish, jaspery rock with irregular streaks and bands of quartz, and apparently chalcedony. Some beds at the foot of the rapid are rich in hard hematite, and make a good iron ore. An analysis of the ore at this place gave the result given in I of the accompanying table:

	I.	II.
Silica (SiO_2),	8.25	3.62
Alumina (Al_2O_3),	Trace	Trace
Ferric oxide (Fe_2O_3),	92.08	95.76
Lime (CaO),	Trace	Trace
Magnesia (MgO),	Trace	Trace
Phosphorus (P),	.09	.093
Sulphur (S.),	.01	None
Manganese (Mn),	None	None
Titanium oxide (TiO_2),	None	......
Total,	100.43	99.473
Metallic iron, -	64.45	67.03

The taconyte is known in numerous test pits to the east of Prairie river in T. 56–24 W. Some bodies of ore have already been discovered, and others will probably be found in the area of this plate. Among the bodies of ore may be mentioned the Diamond mine in S. E. ¼ S. W. ¼ sec. 15; near Griffin's camp in N. E. ¼ sec. 22; on the land of the Arcturus Iron company in S. ½ sec. 13 and N. ½ sec. 24. An anal-

ysis of the ore from Griffin's camp is given in the accompanying table (II), and nineteen determinations of iron and phosphorus from the test pits of the Arcturus Iron company will be found below:

	Metallic iron.	Phosphorus.
No. 1,	63.65	.033
No. 2,	62.70	.037
No. 3,	63.20	.040
No. 4,	59.73	.050
No. 5,	58.01	.050
No. 6,	60.50	.041
No. 7,	57.81	.031
No. 8,	56.68	.035
No. 9,	59.50	.046
No. 10,	63.65	.035
No. 11,	64.40	.057
No. 12,	62.90	.050
No. 13,	57.25	.039
No. 14,	55.68	.040
No. 15,	54.90	.024
No. 16,	66.13	.022
No. 17,	67.18	.020
No. 18,	68.38	.018
No. 19,	62.70	.032

Average: Metallic iron, 61.26; Phosphorus, .037.

The Cretaceous. In the test pits of the Arcturus Iron company in S. ½ sec. 13, and N. ½ sec. 24, T. 56-24 W., Mr. H. V. Winchell informs us that there is a thickness of a number of feet of Cretaceous shale which is highly fossiliferous. These fossils have not been studied, but in all probability they are of the same age as those found a few miles to the east, which are regarded as belonging to the Colorado formation of the Upper Cretaceous.* Other Cretaceous areas are quite likely to be found within the district included in this plate.

GEOLOGICAL MAP.

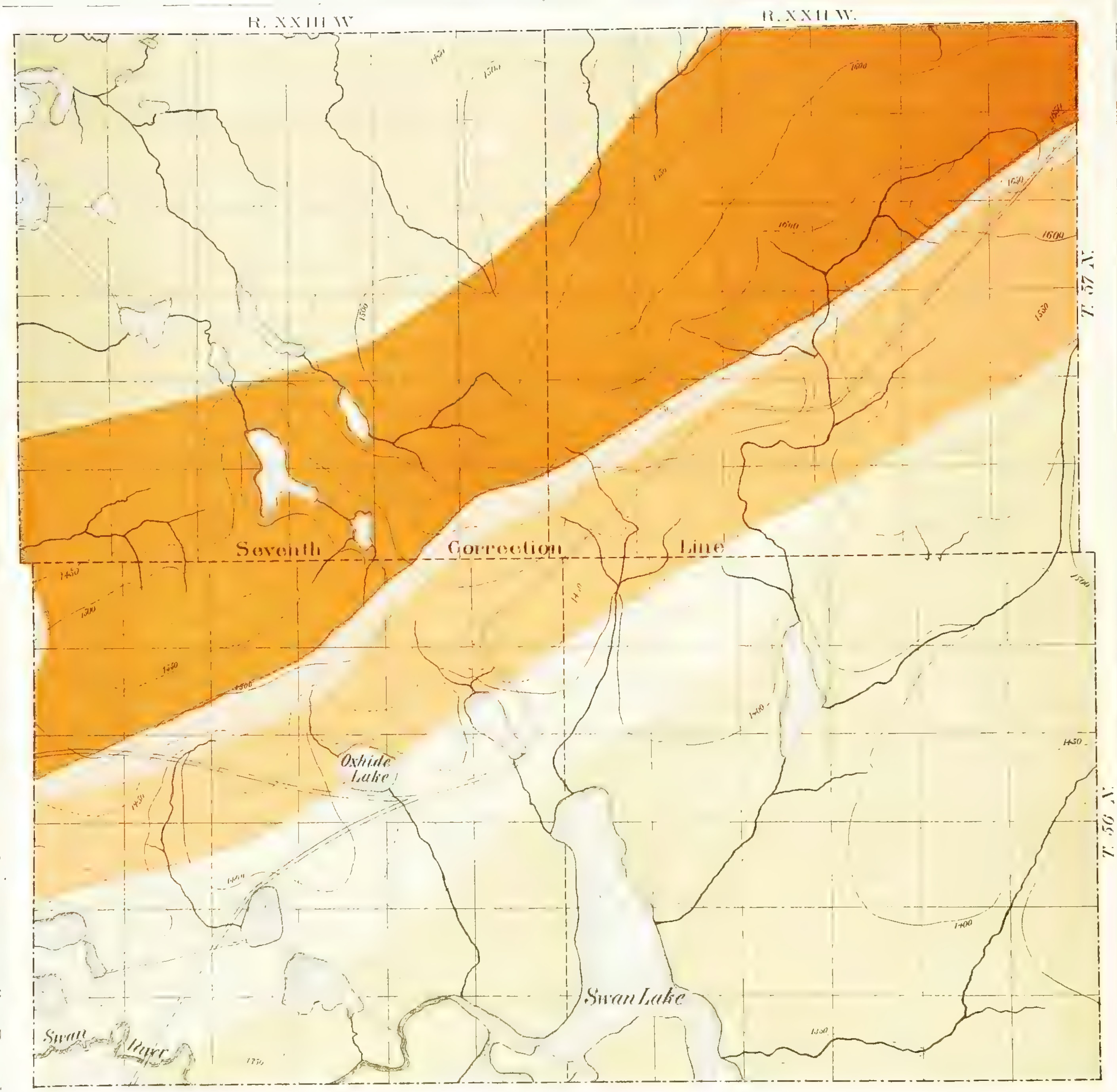
The data at hand cause us to feel reasonably sure that the line between the granite and the quartzyte, as well as that between the latter and the taconyte or iron-bearing member of the Animikie, is located accurately, except possibly for the area of the irregularity in the strike of these rocks in the northeast corner of the plate. The granitic rocks most probably extend to the northwest, under the drift, beyond the limit shown on the map, and the taconyte may extend farther to the south than is indicated. But in each case the formations are mapped as covering only those areas where outcrops (or test pits in the rock) occur. The contour lines were obtained with the aid of an aneroid barometer and may be regarded as approximately correct.

ROCK SAMPLES.

The following rock samples were collected within the area of this plate:

N. H. Winchell's series: Nos. 1522-1537.
H. V. Winchell's series: Nos. 260-280; 283.

* *Amer. Geol.*, vol. xiii, pp. 220-223.



GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA

SWAN LAKE PLATE

COMPILED BY U. S. GRANT

Contour Lines [illegible]
[illegible]

Explanation

Glacial		*Drift unstudied*
		Drift, probably moraine
Animikie		*Taconyte or iron bearing member*
		Pokegama quartzyte
Archean		*Granitic rocks*
		Roads
		Fifty foot contours
		Hundred foot contours

CHAPTER XV.

THE GEOLOGY OF THE SWAN LAKE PLATE.*

By U. S. GRANT.

Situation and area. The district included in this plate lies on the eastern side of Itasca county and contains Ts. 56–22, 56–23, 57–22 and 57–23, all west of the Fourth principal meridian. It is thus twelve miles square and contains 144 square miles. It includes the Mesabi iron range between the Grand Rapids plate (plate 71) on the west, and the Hibbing plate (plate 73) on the east.

SURFACE FEATURES.

The land surface is similar to that of the other plates in this part of the Mesabi range, being in its southern part flat or undulating, while farther north the surface is hilly. The Giant's range, the ridge which lies just to the north of the Mesabi iron-bearing rocks, is a marked topographic feature, rising 250 to 300 feet above the lower land around Swan lake. This ridge is composed of granitic rocks and it forms the divide between the streams which flow north and northwest from those which flow south. The former streams find their way to the Prairie river, and the latter to the Swan river, both of which streams are tributary to the Mississippi.

The east line of the plate is also the west line of St. Louis county, and from notes taken along this line we know that from the southeastern corner of the plate north for about two miles the surface is covered with modified drift deposits—sand and gravel. North of this, until coming to within two miles of the northeastern corner of the plate, the surface is composed of unmodified till, flat or undulating in character, and frequently swampy. In the last two miles before reaching the north-east corner of the plate the surface is knolly and hilly, and the drift is characteristic of terminal moraine deposits. This moraine is supposed to extend westward, near the north line of township 57, and to connect with the Mesabi or Tenth moraine which is developed, known in the vicinity of Trout and Wabano lakes in T. 57-25 W. (See map of Itasca county, plate 65.) The Itasca or Ninth moraine enters the plate near its southwestern corner and extends northeastwardly, as shown on the map.

* For information concerning the various rock outcrops and test pits in this plate we are especially indebted to Mr. R. M. Bennett, of Minneapolis. The author is not personally acquainted with this district.

It is finally thought to cross the iron-bearing rocks in T. 57–22 W., and to unite with the Mesabi moraine near the northeast corner of the plate.

GEOLOGICAL STRUCTURE.

Granitic rocks. As far as known, these rocks in this plate are of the same general character as similar rocks elsewhere on the Giant's range in this vicinity, and outcrops are not uncommon. Dark hornblendic rock or dioryte is reported from sec. 25, T. 27–23 W., but how large an area is occupied by this rock is not known. It may be a mass of hornblendic schist similar to that shown on the Hibbing plate (plate 73) north of the iron-bearing rocks.

Specimens of the granite from the S. W. ¼ S. W. ¼ sec. 33, T. 57–23 W., show a rather fine grained, reddish gray, biotite, hornblende granite. The specimens collected here are most probably, though not certainly, in place.

The Animikie. As elsewhere in Itasca county but two divisions, the quartzyte and taconyte members of the Animikie, are known. The rocks and relations of each member are the same as for the Pokegama Lake and Grand Rapids plates.

(1). Pokegama quartzyte. This occupies a narrow belt, not exceeding half a mile in width, between the granite and the taconyte or iron-bearing member. Outcrops are known from a number of places, especially in the N. W. ¼ of sec. 10, T. 56–23 W. The small area of quartzyte shown on the map in the west side of sec. 6, T. 56–23 W., has been explained under the discussion of the quartzyte in the description of the Grand Rapids plate.

(2). Taconyte or iron-bearing member. Numerous test pits within the area of this plate strike this rock, especially along the eastern side of the plate in secs. 13 and 24, T. 57–22 W. Many ore bodies have not yet been reported from the district included in this plate, but there seems to be no reason known why they will not be found by farther search. The Mesabi Chief mine, in S. W. ¼ sec. 23, T. 57–22 W., is one of the first places where a large deposit of ore was found in this plate.

A diamond drill hole in the taconyte in the N. W. ¼ N. E. ¼ N. E. ¼ sec. 1, T. 56–23 W., passed through the following strata:

	Feet.
Drift,	1
Banded lean ore,	58½
Banded ore and taconyte,	16½
Banded taconyte,	32¾
Lean hematite ore,	33¼
Banded lean ore and taconyte,	3
Taconyte and gray slate,	32½
Thin seams of ore,	53½
Quartzyte,	4⅓
	235⅓

This shows that the taconyte at this place has a thickness of 231 feet. It is believed that this does not represent anywhere near the total thickness of the taco-

nyte horizon in this vicinity, the upper part of this formation having been removed, in the vicinity of this diamond drill hole, by erosion.

GEOLOGICAL MAP.

The reported exposures and test pits furnish sufficient data to enable us to mark out the north and south limits of the quartzyte belt quite accurately, although, for a distance of four miles northeast from the west side of sec. 31, T. 57–22 W., the limits may not be as accurate as elsewhere. The northern limit of the granitic rocks and the southern limit of the taconyte rocks are not known, the limits shown on the map being simply those beyond which we have no records of outcrops or of test pits in the rock. The data for contour lines are very imperfect, and these lines are to be regarded only as rough attempts to indicate the general elevation of the surface and the location of the more elevated tracts.

ROCK SAMPLES.

The following rock samples were collected within the area of this plate:

H. V. Winchell's series: No. 281.
J. E. Spurr's series: Nos. 229, 230.

CHAPTER XVI.

THE GEOLOGY OF THE HIBBING PLATE OF THE MESABI IRON RANGE.

(PLATE 73.)

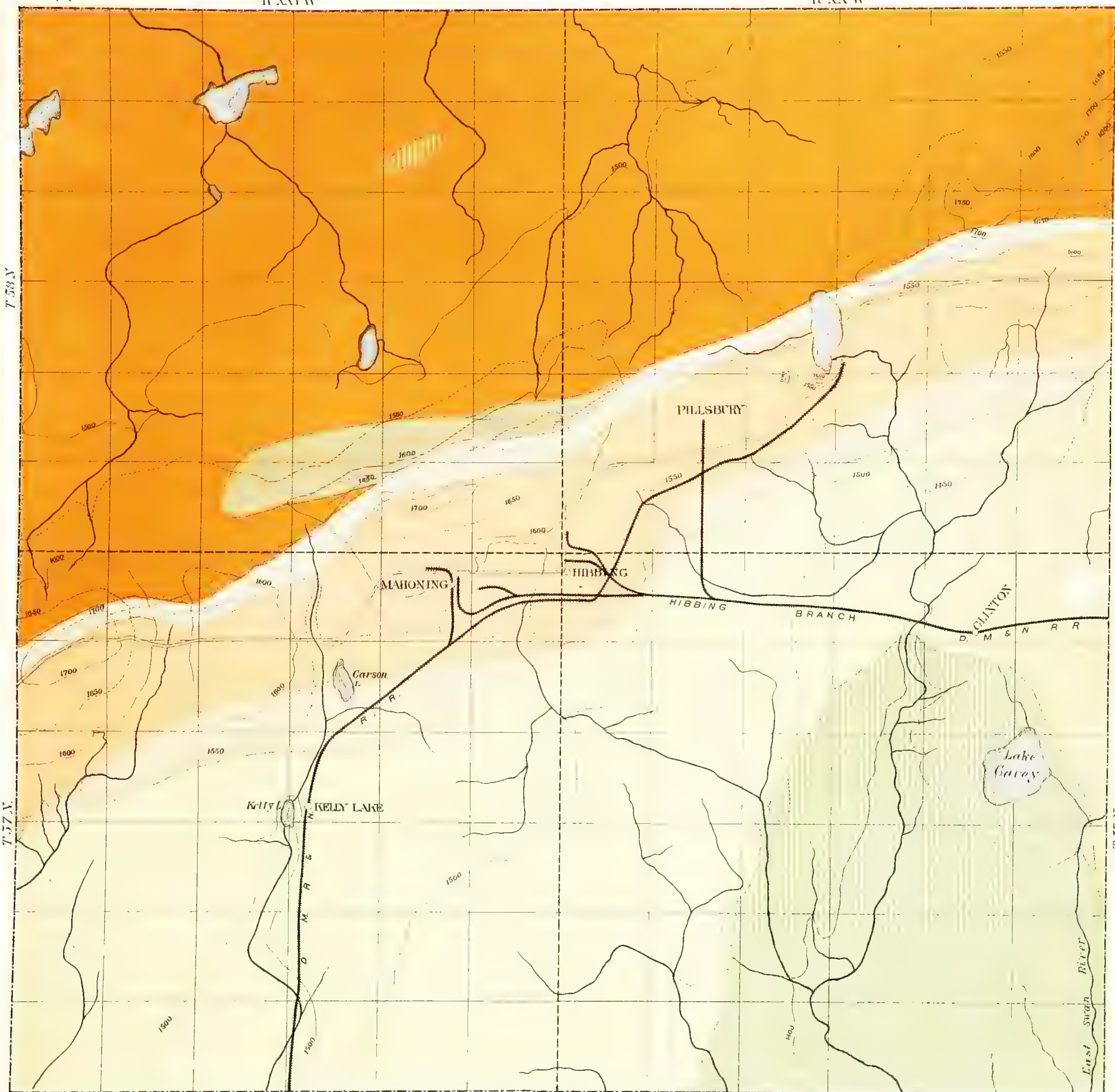
BY N. H. WINCHELL.

The water-divide formed by the Giant's range of granite is less prominent as a topographic feature in the area of this plate than in those next east.* Its greatest elevations are in the extreme northeastern part, in sec. 12, T. 58-20, where a small area has an altitude of 1,800 feet above the sea, the adjoining lowlands being at 1,500 feet, a difference of 300 feet. Further west, while the highest points are 1,700 feet, the adjoining country is 1,500 feet. The slopes from this divide are gentle on either side. On some extended tracts the actual trend of the water divide is not outwardly observable, except by the directions of the small streams. It does not always follow the area of the granite. The quartzyte, being more nearly a flat-lying stratum, sometimes forms the chief elevation, rising with the inequalities of the underlying granite. Even the taconyte horizon is sometimes brought to do service as the highest rock in the region, as occurs in the ridge in sec. 35, T. 58-21. The summit of the divide passes into the granite area in the northeastern part of T. 58-20, where the country becomes rugged and greatly in contrast with the gentle inclines of the Animikie area further west.

The quartzyte, which is the bottom layer of the Animikie, is not always observable, but the taconyte member apparently overlaps it, as thought by Mr. Spurr, or swells downward so as to include the horizon of the quartzyte within that of the iron-bearing member. The same irregularity occurs on the Mesabi iron range much further east. The quartzyte is visible continuously, however, as far east as in sec. 21, T. 58-20, where it dwindles to a narrow wedge and disappears, the taconyte apparently coming into contact with the granite. A narrow strip occurs again in section 14, which is known to extend but little over a mile.†

*The data for this description are derived mainly from the survey of Mr. J. E. Spurr as published in *Bulletin x*, supplemented, however, by later information from Dr. U. S. Grant. The accompanying plate is reconstructed from that of Mr. Spurr, with slight alterations.

†Later examinations made by Dr. Grant in the fall of 1898 indicate that the basal quartzyte is more nearly a constant member than is above supposed.



GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA

HIBBING PLATE

BY N. H. WINCHELL

Explanation

Modified drift
Glacial drift Till

Taconic:
- *Black slates* (Animikie)
- *Taconyte* (Animikie)
- *Quartzyte* (Animikie)

Archean:
- *Granite Post Keewatin*
- *Mica schists Keewatin*
- *Greenstones*

— *Railroads*
Wagonroads
Fifty foot contours
Hundred foot contours

Contour Lines

The iron bearing strata, and all the members of the Animikie, pass evenly across the area represented by this plate, as far as known, with the exception of the slight irregularities in the Pokegama quartzyte above noted. The dip is slight, or almost flat, giving these strata greater width in their surface extent than at points further east.

The survey of this area having been made prior to the developments of the important mines, now in operation at and near Hibbing, and before the railroads were built, it is impossible, without further examination, to give the details of the geology. The following mines are in operation within the area of this plate: Mahoning, Hull, Rust, Burt, Day, Pillsbury, Sellers, Penobscot.

The following hand-samples of the rocks of this area were collected by Mr. Spurr: Nos. 138S, 205S, 206S, 207S, 208S, 210S, 211S, 212S, 213S, 214S, 215S, 216S, 217S, 218S, 219S, 220S, 221S, 222S, 223S, 224S, 225S, 226S, 227S, 228S.

For descriptions of thin sections of some of these the reader may consult Mr. Spurr's report* on the Mesabi iron-bearing rocks, also another portion (vol. v) of this report, under petrographic geology.

Mr. Spurr has shown that the iron ores of the Mesabi iron range have resulted from a metasomatic alteration of a rock having in the main the composition of glauconite. Inasmuch as one of the series of rocks on which he based this conclusion were derived from the area of this plate, it is appropriate to give in brief the method of the examination, and the steps of the process through which the change has been carried on.

The macroscopic examination consisted in the selection of a series of over two hundred samples from all parts of the range, and the classification of them according to their outward appearance without microscopical or chemical aid. He grouped these specimens into thirty-two phases. Many of them differed but little from one another, but as they manifested slight variations, and might have come from different sources or directions of alteration, they were all enumerated. He had, for instance, six forms or types of iron ore,—magnetite, hard crystalline hematite, friable granular crystalline hematite, earthy hematite, and earthy limonite or gœthite. The rocks were equally differentiated on the basis of their macroscopic characters.

These thirty-two phases were found to be capable of a general grouping into eight classes. They also grade into each other, and the classes also have points of consecutive alliance. In short, the appearance showed that the phases are derived one from the other, and in nearly all of the specimens the change could be seen in progress. Frequently two or more phases could be seen in a single specimen, the line separating them being irregular, or the two phases being inter-banded, sometimes in several alternations. Sometimes these bands wedge out and disappear,

* *Bulletin x*, pp. 82–89.

allowing the union of its neighbors, and sometimes they curve. These variations are sometimes ascribable to common weathering, and in other cases they are more deep-seated. By careful comparison the relative ages of the different phases were sometimes established. One phase could be seen to pass into another, or into two or three others, in the same specimen. Every specimen was thus inspected, and after tabulation of the results, and a re-grouping of the observed transitions, it was evident that the changes had a definite order, through the whole series, and that the series had a beginning in a certain rock and an ending in iron ore. The commencement of the series, or the rock from which the various forms of taconyte and all the ores are derived, is a granular, green rock, often with a peculiar mottled structure (No. 14S). It is a hard, green taconyte, sometimes with no visible iron, but usually with streaks or blotches of magnetite.

It would be highly interesting and useful, if it were possible, to assign to these phases definite stratigraphic or other structural positions, in order that in the field an intelligent search could be made for the end phase of the series, *i. e.*, for the iron ore. While it is true that there is a definite progression in a certain chemical direction from phase to phase, yet the conditions of exposure to the agents that promote the changes are so multitudinous that the series is not, by any means, consecutively arranged in structural order. They are much more advanced in some places than in others. Even stratigraphically there is only a very broad general succession that can be asserted. The iron ores are sometimes higher in the strata at one point than at another, although confined to the general taconyte horizon. In the same manner the various phases of alteration are found to shift about from top to bottom of the iron-bearing member, and no one of them is distinctly referable to a certain horizon. The cherty and slaty rocks, however, seem to occur in large bodies in the upper horizons, and the clayey and pulverulent slaty rocks are found at the surface at any horizon, and lying above the less altered rocks to which they are akin. Ordinarily those phases which are near the end of the series, and which therefore represent the greatest decomposition, are found near the surface, and, in general, those less altered are at greater depths. But the effects of surface weathering and other changes *in situ* cause many irregularities.

The microscopic examination of these rocks followed the foregoing general classification and gave many confirmatory facts in detail, which led to other interesting and important conclusions. In this minute search but a small area could be included at once. The various phases were examined. Some of the phases were found in close proximity, even in the same specimen, and in the same microscopic slide. It was by pursuing the grander phases to their microscopic conditions, where they were nearest their nearest allies, that the microscopical evidence was found to bear out

the macroscopical conclusions. A group of specimens for such comparison were collected on sec. 22, T. 58–20. They are Nos. 213S, 215S, 217S, 219S and 220S. Eleven such groups were microscopically examined. The phenomena of each section were carefully noted, and from them the conclusion resulted, in each instance, that the phases exhibited in the slide were derived from each other in a certain order, as proven by the alterations in the microscopic minerals, and always in the same order; that the initial rock in the series was the hard green rock (No. 39 or 53–1) already mentioned, made up largely of glauconitic matter, and that by the breaking up of this unstable chemical compound resulted oxide of iron and silica, in the main, with small amounts of lime and alumina. The iron oxide, being more soluble, was carried to other places, while the silica accumulated in greater proportion *in situ*, making the siliceous and cherty rocks that characterize the lean ores. Chemical analyses were made to check most of the microscopical conclusions. The following extract from Mr. Spurr's report shows the nature of the microscopic characters studied, as well as the thoroughness with which the research was conducted:

Section 217. This is nearly identical, both macroscopically and microscopically, with No. 125. In the hand-specimen it is dark-green, very faintly spotted and contains small blotches, bands and spots of magnetite. There is an irregular jointing, but no cleavage; the fracture is conchoidal; the specific gravity rather high. Under the microscope, the spotted-granular structure is well shown. The granules are rounded, subangular, or irregular, and are closely crowded together. They consist mainly of the compact green chloritic* substance described in Nos. 39, 125, and other slides, together with actinolite, magnetite, hematite and siderite. Magnetite, in very small crystalline grains, and with associated hematite, is usually scattered sparingly through the granules, but is in places concentrated as described in the hand-specimen. The process of granular-brecciation is seen to be going on in some parts of the section, where the large, angular granules are sometimes cracked and seamed by fissures of varying width; sometimes separated into distinct smaller granules by an enlargement and continuation of these fissures; and again further separated and rounded, but their general outlines continuing such that they nearly match one another.

The green chloritic mineral has never any crystal outlines, but it encloses crystals of magnetite, and in places, under high power, it is seen to contain many very minute clusters of pale-green, pleochroic actinolite. It is slightly pleochroic, varying from lighter to darker green, and often shows an irregular cracking. In places this mineral occupies the whole of the granules; in other places it becomes filled with silica in spots and fissures; then it is reduced to form a kind of network around the silica; and finally the granule is composed almost entirely of silica, with only a few dust-like grains, giving a cloudy greenish appearance, to mark the existence of the chloritic substance. From the chloritic granules to the siliceous granules, there is every conceivable gradation, and one runs into the other so that it may be seen to be a process of metasomatic change. In the freshest phases the chloritic substance is marked only by a slight mottling of lighter and darker green. Soon, however, there appear scattered through it curious small dark rings. By nice adjustment under a high power the real material of the ring is seen to be a very narrow band of transparent silica. It is extremely fine, and varies from an apparently amorphous to a finely cryptocrystalline or chalcedonic nature. The number of these rings rapidly increases in the next stage, till the whole surface is covered with them. They grow larger, too, in both directions, so that on the outside they meet and unite, forming compound rings, and rosette-like forms, and on the other side the material inside the ring becomes smaller. It also becomes darker in color than at first, apparently from a growing excess of iron, in some cases becoming quite opaque. In the next stage the change has gone on till the silica has usurped most of the space in the granules. The chloritic substance, grown darker and nearly opaque, forms a compact network around the silica. The chloritic centre of the rings has in most cases disappeared, in others is represented by a very small patch of ferruginous clayey material. By this time the silica has often assumed a distinctly chalcedonic nature. It is usually made up of fibres that radiate from the inner core of the ring, or, if this has disappeared, from the centre of the circle, and terminating at the circumference. In proportion as the circle grows larger and tends to unite with others this fibrous structure becomes obscure and passes into a semi-crystalline condition, in grains that have an undulatory extinction and low polarization colors. In the last stage the chloritic substance has disappeared, and the silica occupies the whole granule, except for the cloudy residuum which gives it a color sufficiently distinct to contrast strongly with the colorless silica of the interstices. The silica at this time is semi-crystalline, semi-chalcedonic. Only occasionally are the traces of the

*The substance here referred to as "chloritic" was afterwards discovered to be glauconitic.

fibrous arrangement met with, and yet there is no firm crystalline structure. There seems to be a tendency, however, for each of the original rings to form, when crystallized, a distinct grain. There may be found single granules which represent each a stage of the process of change described, but usually all the stages are seen going on in the same granule, passing from the nearly pure chloritic substance to nearly pure silica. Actinolite forms a small part of the section, perhaps five per cent. It seems to be invariably of secondary origin, since it is found chiefly around the edges of the granules, from which the crystals radiate into the inter-granular spaces.

Although the chief method of silicification of the granules is by the process described, there is an important auxiliary. In many cases silica which is probably foreign to a granule penetrates along cracks which have been produced by some movement in the rock, and enlarges them by wedging and by replacement of the wall-material; and in this way continually divides the granule into fragments. Cracks which traverse the whole rock, on the other hand, usually give rise to impregnation veins, along which chiefly magnetite, with some hematite and calcite, is concentrated.

That the silica which takes the place of the chloritic substance is formed from its decomposition, and not from replacement, is shown by the method of distribution of the change, in that it does not begin at the periphery or in mechanically weak places, but appears simultaneously in all parts of it; so that portions remote from other silica and outside influences are quite as much affected as any. Moreover the separation of earthy iron oxide, coloring the remaining chloritic substance a dark-brown, is proof that a decomposition has actually taken place.

Conclusion. This rock is near the beginning of the typical series of change. As in other similar sections, the original rock seems to have consisted chiefly of a chloritic substance. In the decomposition of this substance there has resulted the separation of free silica together with iron and the more soluble salts. These soluble materials were almost totally leached out; the iron, less soluble, was taken into solution and mainly deposited near by, and is represented by bands and blotches of considerable size and frequency. What few carbonates are scattered along the microscopic impregnation veins are probably also derived, through this change, from the original green chloritic substance. They are chiefly calcite, probably magnesian. The processes observed in this rock, it will be seen, have gone on under conditions of comparative freedom from modifying highly oxidizing forces. Had the supply of these been somewhat greater, and yet not great enough for complete oxidation, the iron would have separated as carbonate, and in this form would have occupied more of the bulk of the rock. This carbonate would probably be afterwards *replaced* by silica, by reason of its greater solubility. In the rock under consideration waters bearing carbonic acid had slight access, and so separated silica is the most noticeable result of this change. It is this silica, taken into solution and carried down into the rock below, that would in turn replace the carbonates formed under our supposititious conditions.

An analysis of this rock gave the following results:

Analysis of No. 217S (Chemical series No. 241) by Alonzo D. Meeds.

	Per cent.
Silica (SiO_2),	56.28
Sesquioxide of iron (Fe_2O_3),	15.25
Protoxide of iron (FeO),	18.28
Alumina (Al_2O_3),	3.29
Lime (CaO),	.93
Magnesia (MgO ,	.72
Soda (Na_2O),	.25
Loss on ignition,	4.75
Total,	99.75

It must be remembered that this analysis is independent of the iron which has been concentrated into spots and bands. Its place has been filled with silica. Nearly all of the iron which has become separated by decomposition of the silicates has been removed in this way. In any attempt to estimate the exact composition of the original rock this must be reckoned, and the corresponding amount of silica deducted.

The change which is described in rock No. 217S is illustrative of what has pervaded the whole iron-bearing member. It is a metasomatic change affecting strata whose greatest thickness seems to be nearly 1,000 feet. The removal of the protoxide of iron by solution and its concentration at certain favorable points where oxidation was more easy and rapid, resulting in the ore lenses that are now well known, was a process that probably began as soon as the material was consolidated into a rock, was essentially completed in its present aspect in pre-Cretaceous time, but has continued to the present, and there is room for its continuance for very a long time yet. The initial cause of the change is the chemical instability of glauconite. The protoxide of iron, even under very feeble atmospheric influences, rapidly changes to sesquioxide, and

with the lapse of sufficient time this alteration will penetrate to great depths under normal and steady conditions. But when, by reason of unusual conditions, the process is hastened, then locally the extremes of the alteration are produced in marked abundance, and even in close proximity. If these unusual conditions are continued long enough, there result large bodies of these end products, viz., iron and silica. Such unusual conditions seem to have prevailed on the Mesabi Iron range in some places and not in others, viz.: (1) Rock movements, producing a shearing and slatiness in the original rock, allowing the rapid entrance of the agents of alteration to greater depths; (2) More profound and catastrophic changes in the structural relations of the strata, such as a fault-line, or an uplift bodily of the strata over a certain belt; (3) Accidental juxtaposition of strata by whose atmospheric destruction the chemical agents are abundantly supplied locally to the iron-bearing member. These exceptional conditions have united sometimes, and have augmented or modified each other's products; for instance, the gray limestone stratum which directly overlies the iron-bearing member with a thickness of ten to fifty feet, by its solution and removal has furnished not only calcareous waters, but also carbonated and sulphurous, introducing calcite and pyrite into their alteration products.

While these slow chemical changes are going on the main structural features are preserved throughout the mass of the rock. After the changes are completed the rock exhibits still nearly all the outward aspects of a sedimentary rock. The original clastic composition is, however, entirely destroyed, and the products are held in place by the crystallization of the secondary minerals. In the main the secondary products simulate, in this structure, as they are partially governed by them in assuming their positions, the original structures of the rock, but there is one important result which needs to be specially mentioned, as it constitutes a marked exception. The breaking up of the green glauconitic rock into silica and iron, with some carbonate and actinolite, produces a banded structure, under the action of the varying solubilities, which is well known as jasper or jaspilyte. According to Mr. Spurr the banded jaspers, such as those seen in the Vermilion Iron range on a grand scale, and rarely in the Mesabi Iron range, have resulted from a metasomatic breaking down and total change in that which is typically known on the Mesabi range as taconyte jasper (or taconyte). Mr. Spurr explains by the same general process, continued through long lapse of time, all the structures seen in the Mesabi iron-bearing rocks, such as jointage, cleavage and horizontal banding or bedding. The last is that which simulates sedimentary structure and which has usually been considered as such. This structure prevails not only in the partially altered rock but in the ore that is mined.

In another place the question of the origin of the Mesabi ores, and their analogies and contrasts with those of the Vermilion range, is considered in this report. It

is only necessary here to add that the research of Mr. Spurr, conducted with thoroughness and originality, making it a model of inductive geological investigation, seems to have settled conclusively the question of the origin of the Mesabi ores. The writer had concluded, after his first survey in the field about the time that Mr. Spurr began his field-work, that no adequate solution of that question had yet been proposed,* although all the theories applied to this ore had some facts that served as a basis on which they were severally constructed. There are minor steps in his chain of evidence, not essential to Mr. Spurr's main conclusion, that may be considered yet of doubtful validity. Such are (1) The existence of a fault-line of important dimension in the Virginia area; (2) Brecciated character of the loose ore, etc., to which he refers to substantiate the hypothesis of a fault at Virginia; (3) The non-sedimentary structure of the ore and of the iron-bearing rock, and (4) The assignment of the kaolinic residue, without exception, to the ore-bearing formation. Some, if not all of it, is probably of Cretaceous age. A few doubtful determinations of the minerals in the microscopic thin sections will be found discussed in the chapter on the petrographic geology of the northeastern part of the state.

[In the fall of 1898, Dr. Grant made a brief examination at Hibbing. From his notes the following facts are derived: At the Pillsbury mine, where is seen some open pit work, the ore dips to the southeast at about 15°, varying somewhat. In the underground working there is a drift running west from the shaft about 800 feet, cut in ore. The floor of this drift is taconyte rock underlying the ore, ascending toward the west at an angle of about 6°. The drift runs at the bottom of a broad syncline, and cross-cuts in either direction rise from the level of the drift at a moderate angle, their floors also consisting of taconyte.

At the Mahoning great open pit, the ore dips off pretty regularly, with only small variation, toward the south or a little east of south at an angle of 8° to 10°. This mine exhibits the largest open pit now in operation on the Mesabi range, the ore being handled by steam shovel and dumped directly on the cars at a minimum cost for mining. It is located a mile and a quarter west of Hibbing. There are several other mines to the southeast and south from the Mahoning, which are so situated that it is probable that they are on the same ore body as the Mahoning.]

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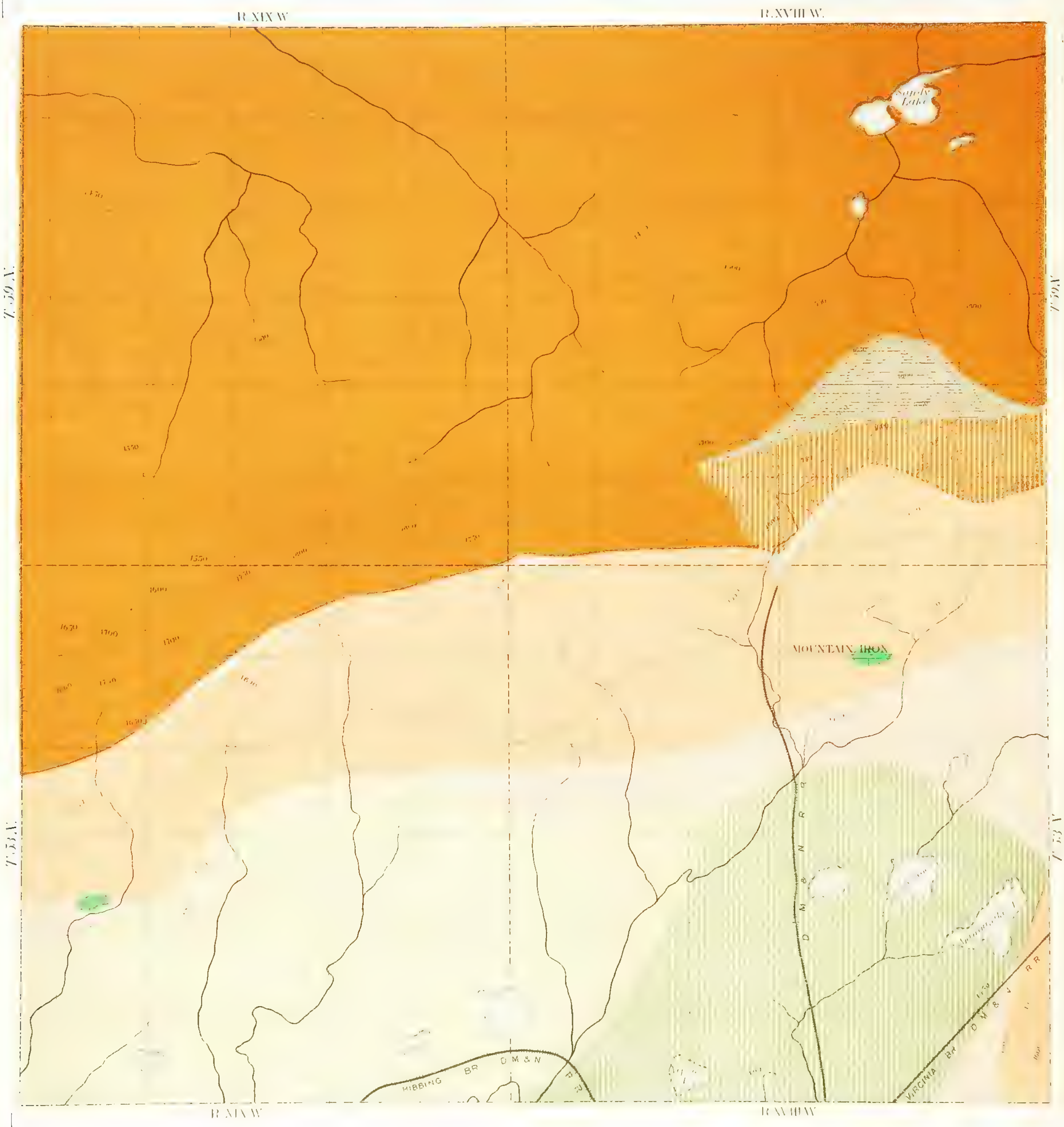
*N. H. WINCHELL. Some problems of the Mesabi iron ore. *American Geologist*, 10, 169, 1892.



GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA

MOUNTAIN IRON PLATE

BY N H WINCHELL

Explanation

Railroads

Fifty foot contours

Hundred foot contours

Contour lines

CHAPTER XVII.

THE GEOLOGY OF THE MOUNTAIN IRON PLATE OF THE MESABI IRON RANGE.

(PLATE 74.)

BY N. H. WINCHELL.

The first important discovery of iron ore on the Western Mesabi range was made at Mountain Iron, November 16, 1890, by Capt. J. A. Nichols, of Duluth. Several explorers had examined the siliceous out-cropping which lies near the granite on this property, and had made some attempt to prove its value, but no one had been satisfied with the results. When, however, some shafting was done at points a short distance south from this cropping, the pick soon entered a rich soft hematite below but a few feet of drift materials. The structural relations thus revealed are expressed by the following diagram.

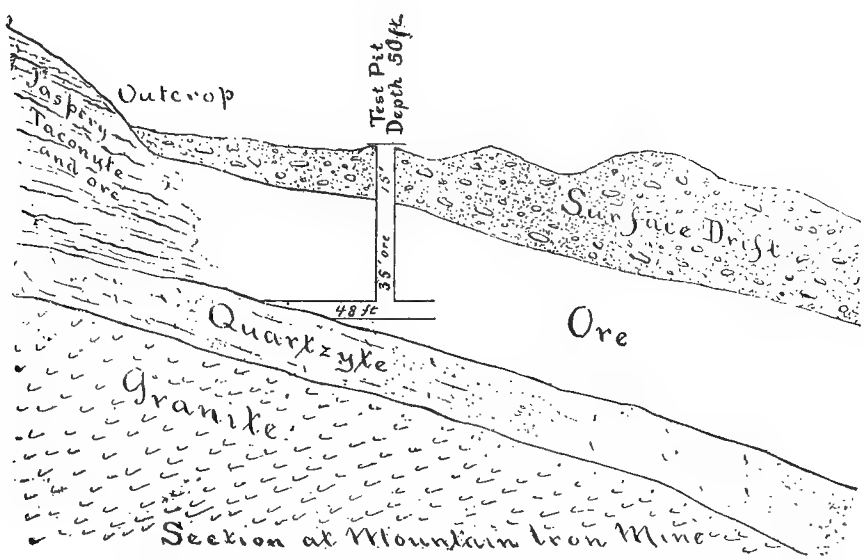


FIG. 62. ORIGINAL SECTION AT THE MOUNTAIN IRON MINE.

Although the relations of the ore horizon to the jaspery taconyte are plainly revealed here, and were afterwards observed at many places with equal distinctness, it required long and careful study, preceded by field examination at many points,

to arrive intelligently at the conclusion that a principal member of the formation was transformed into iron ore by the slow process of chemical change and underground transportation.

The crystalline rocks. As usual the crest of the Giant's range is composed of the crystalline rocks. But in T. 59–18 a considerable area of Keewatin and crystalline schists rises to compose the summits of this range, reaching the hight of 1,850 feet in section 26. The slopes toward the north are sometimes abrupt, indeed they are uniformly more steep than toward the south. Northward from the summit of this hill range no rock is known within the area of this plate, except the Archean granites, gneisses and schists, and granite is the prevalent rock along the range itself. This has plainly been intruded within and modified the Keewatin schists, producing by the contact metamorphism the formation called Coutchiching. The characters of the Keewatin are not known to be different in the aggregate from those seen and described in other places, particularly in connection with the Vermilion Lake plate (No. 86). The Coutchiching or crystalline schists are micaceous, rarely hornblendic. Sometimes they are quite light-colored and strongly schistose (No. 60S) with abundant glittering small muscovite scales. In other cases it is much darker, firmer and apparently is composed largely of biotite. It then has cores or small, faintly pink areas in which other minerals are crystallized (No. 59S), and in which the schistosity is wanting. These more massively crystalline small eyes are probably due to the same causes as the gneissic aspects which are largely developed in the northwest area of Vermilion lake (compare the Vermilion Lake plate No. 86), and which introduce a regional metamorphism which extends sometimes over several miles, or even several townships.

The southern decline of the granitic surface is probably more steep than the northern, but it is covered by the Animikie, which renders the actual surface slope much more gentle.

The Pokegama quartzyte, which lies nonconformably on the Archean, has a varying thickness. Indeed, it is sometimes apparently absent, and the iron-bearing strata come into contact with the crystalline rocks. There is reason to suppose that, in some places, the quartzyte is only a phase within the iron-bearing member, confined to the bottom of the Animikie, and that normally the quartzyte is not a continuous formation. Sometimes it is coarsely granular with quartz grains. These grains are apt to be cemented into a dense rock by secondary silica, or stained by ferric oxide. Indeed, they are sometimes so completely charged with iron that the rock constitutes a siliceous lean ore, and it has been explored with hope of economic profit. Such ore is found on the Republic property, sec. 4, T. 58–18, next adjoining the Mountain Iron. This ore becomes disintegrated, making a pisolitic mass, which, sometimes,

having lost the silica by subsequent solution, consists of more or less cavernous, oölitic balls and hollow grains of hematite. Considerable quantities of such ore are mined. It cannot be said to result entirely from the disintegration of the upper part of the quartzyte after the substitution of much hematite, but probably also comes in part from the lower part of the iron-bearing member proper, since it also sometimes shows a loosely pisolitic ore embraced in a matrix of secondary silica.

The taconyte stratum proper is very productive within this area. Here are located the following mines:

Mountain Iron.
Rathbun.
Sniveley.

The ore horizon, *i. e.*, the rock which by its disintegration gives rise to the Mesabi ores, is several hundred feet in thickness. The ore is not uniformly disseminated through it, but occurs in irregular lenses where favorable conditions have facilitated the chemical processes that break up the original glauconite. Under normal conditions they prevail near the bottom. This process began in early Taconic time and has continued to the present day. There is no doubt that large quantities of the resultant ore have been lost by erosion and superficial transportation. The process was far advanced when the region was submerged by the Cretaceous ocean, and still further when the Glacial period supervened. This ore stains the drift for many miles south of the range, especially along the valleys of the St. Louis and the Mississippi. Great thicknesses of red laminated clay are seen in their bluffs. The loss which the Mesabi ores suffered by the glacial abrasion and aqueous transportation was probably greater than all the ore that now remains *in situ*. On the other hand, the excess of surface waters that accompanied the Glacial epoch must have found access to the rock through many new channels, facilitating and extending the chemical changes that produce the ore, and this tended to compensate for the loss by the generation of new ore bodies during the prevalence and since the withdrawal of the ice.

The Mountain Iron mine occupies a basin situated in the western portion of sec. 3, T. 58-18, elongated nearly north and south, but draining toward the south. The northern, western and eastern rim of this depression is formed by hard rock, and granite is found not far toward the north. The basin seems to be due to some shrinkage or erosion of the rocks of the Animikie, which rocks are in outcrop more or less along the southern border of the granite, having a high dip toward the south, or standing nearly vertical. At the mine the ore alternates somewhat with an impure ore, or taconyte, both having a dip which sometimes reaches 25° or 30° toward the west, well marked and constant, but sometimes is nearly flat, and which also varies to the south and southeast, and locally also changes to the north.

The ore is frequently pisolitic (No. 2137), and concretionary, and in some few instances grains of quartz are at the centres of the pellets. It is also breccia-pebbly, in hard and firm masses, resembling a conglomerate, but this is due to the partial alteration of a once jaspery rock. The residuum of this rock is in the form of jaspery pieces in the leaner ore, about a quarter of an inch thick, flattened, and about an inch and a half in length. These are siliceous and light-colored in some places and more hematitic in others. In other places can be seen a curious fine sand, mainly ore, and shipped with the ore, though evidently of lower grade, each grain of which is compound, the round, oölitic, separate pieces of which are about as large as a mustard seed. The outer scale, or case, is hematite, and sometimes the most of the whole is hematite; but usually the interior is composed of a mass of finer grains, mainly siliceous and compacted, enclosed in the scale of hematite. Such ore lies in a regular layer in the stratification, and is about two inches thick; but similar round, oölitic material is to be seen disseminated largely in other beds above, and includes about two feet of the ore itself.

At the Mountain Iron mine, the ore has been locally torn up by glacial action, and superficially large masses of drift materials are mingled with the ore. These are visible along the west side of the excavation. One mass of gravelly drift is about eight feet, and another about twelve feet, deep, varying from three feet to five feet wide. The appearance here is that of channels cut in the soft ore body by west-flowing streams in the ice age, or near its close, subsequently filled with drift. This is indicated by the non-disturbed condition of the ore body adjacent to the drift. A still more remarkable instance of the action of the drift agents on the ore was encountered at the Fayal mine, described in connection with the Virginia plate (No. 75).

The black slates of the Animikie are so hid by drift that it is impossible to state their characters, but they are not supposed to vary in any respect from descriptions that are given in connection with other plates.

Cretaceous beds are known to exist at some points within this area, and they probably spread much more widely than is now known. On the plate a small area is represented in sec. 20, T. 58–19, and another at the corners of secs. 2, 3, 10 and 11 in T. 58–18; it is also known in sec. 18, T. 58–18. It is not clear but that some of the soft, greenish and white, clayey and kaolinic specimens, which much resemble the leached conditions of the taconyte proper (such as specimens Nos. 89S, 90S, 91S and 92S) may be of the Cretaceous. The Cretaceous being well known for its glauconitic character, it is plain that on decay the same changes, attended by the same phenomena as in the taconyte, might take place. That during the prevalence of the Cretaceous ocean a green sediment was accumulated is shown by the green

matrix that embraces the coarse pebbles of the conglomerate (No. 61S), and by the fossiliferous shale (No. 145S). This sediment is generally reddened by ferric oxide (No. 139S), or replaced by a dark, cherty secondary silica (No. 62S) which constitutes then a very firm conglomerate. As already intimated it is possible that some of the altered rocks that have been referred to the age of the Taconic are of the age of the Cretaceous.

The Drift. There is a heavy drift throughout most of this area. Toward the south the surface is smooth and consists of fine siliceous and clayey, often laminated, materials, evidently the product of wash from the drift lying further north, dating from the Glacial epoch, in the main, but augmented by powerful erosion and transportation at the close of the Glacial epoch, and immediately thereafter. Along the belt of country specially known as "the range," the immediate surface is rolling, and, even when flat, is plentifully strewn with boulders. This is a peculiar feature of northeastern Minnesota. The nature of the immediate surface leads one to expect that the drift materials below the surface are coarse and probably morainic, with much gravel. But such is not generally the case. The drift is clayey till, and the boulders are not abundant. It appears therefore that the great frequency of boulders on the surface of this till must be accounted for in the main by superficial degradation since the till was left by the glacier. It may be considered doubtful whether a marginal moraine in the proper sense can be said to have been formed along the Giant's range in the area of this plate. This rough and stony tract has, however, been considered to be the extension of the Mesabi moraine, and that interpretation can be accepted till more time can be given to this subject, with special reference to its relation to the Mesabi morainic, as known further west. Toward the north the granitic area is rather thinly covered with till and little-washed gravels which only in small degree determine the topographic contours.

Rocks collected in this area are the following:

Series of J. E. Spurr: Nos. 57S–60S; 62S–69S; 71S, 72S; 74S; 79S–81S; 84S, 85S; 89S–93S; 96S–101S; 103S–137S; 139S–156S; 170S, 171S; 174S.

Series of N. H. Winchell: Nos. 2135–2142.

Series of U. S. Grant: Nos. 1073–1079.

CHAPTER XVIII.

THE GEOLOGY OF THE VIRGINIA PLATE OF THE MESABI IRON RANGE.

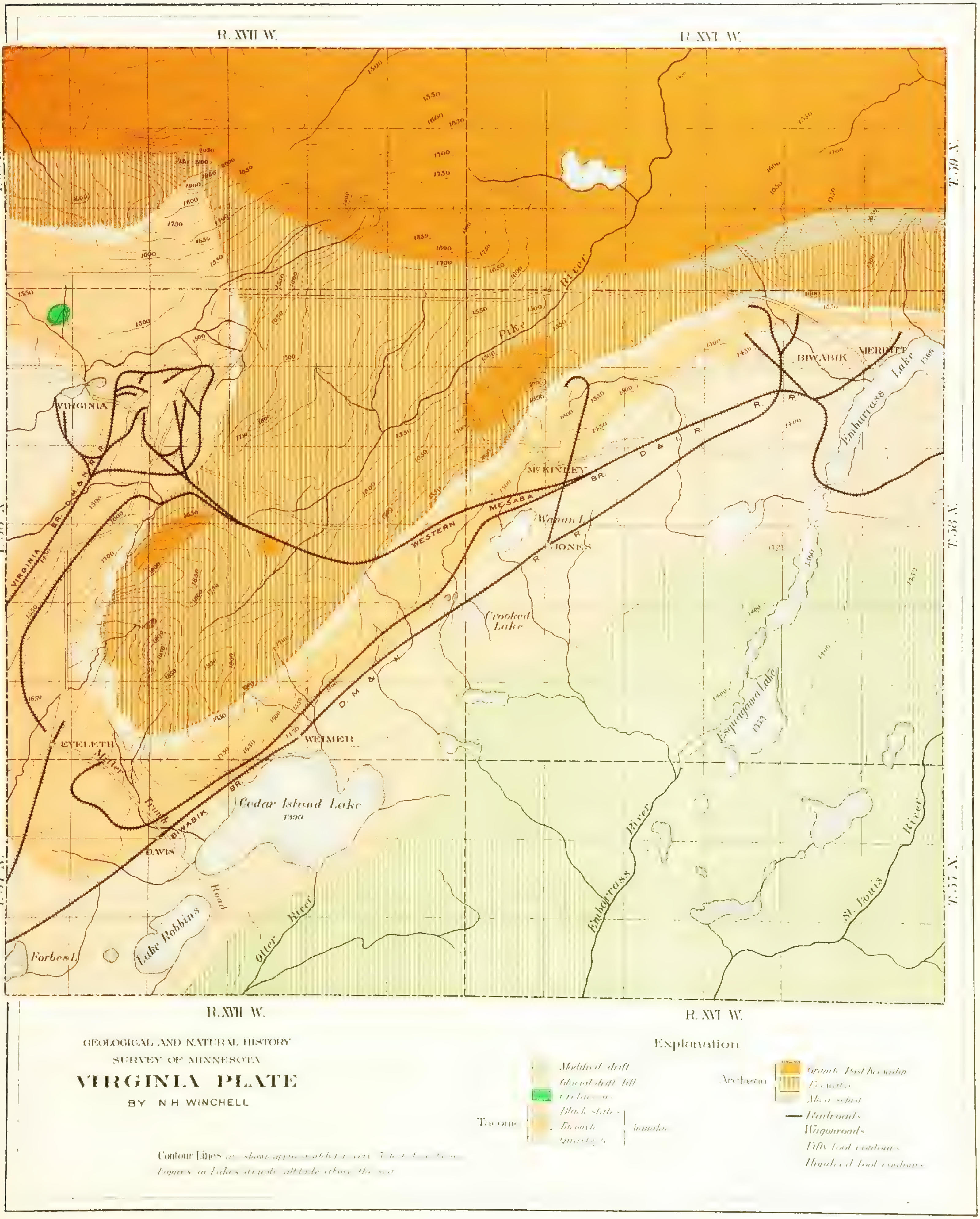
(PLATE 75.)

BY N. H. WINCHELL.

Within this area the rocks of the Mesabi Iron range suffer a remarkable irregularity of strike. They form a loop toward the south, constituting thus the periphery of a spur of the Archean, which projects southerly from the main area a distance of about seven miles from their normal course. The southern end of this spur is high and precipitous, reaching a hight of 1,950 feet above tide. While the most of this spur is composed of Keewatin rocks, yet two isolated areas of crystalline rock are found in it. Between these the land is depressed, forming a low valley drained by the Pike river northward to Vermilion lake, the stream interlocking in its upper reaches with others that flow southward. Along the Giant's range proper the land rises still higher. In sec. 28, T. 59-17, it is in the form of a narrow ridge running east and west about a mile and reaching the elevation of 2,150 feet at its crest. Another isolated and sharp elevation is about two miles further southeast, which rises to the hight of 2,000 feet. On the east side of Pike river, north of Embarrass lake, is an elevated plateau or range of granitic rock. Eastward from this is the great gap in the Giant's range, through which the Embarrass river passes southward to the St. Louis river. The southeastern portion of this area is quite monotonous, and is covered by a thick sheet of drift.

There are several quite novel and interesting features connected with the geology of this area.

The Archean. The later date of the granite than of the Keewatin schists is made evident by an inspection of the contacts. Not only does the Keewatin become crystalline, making mica schists in the vicinity of the granites, but small isolated parts of the schists are surrounded and more or less transported by the granite. These crystalline conditions are represented by rocks Nos. 44S, 45S and 46S. The granite also occurs as protrusions in the schists. The more distant granitic areas, which are isolated and entirely surrounded by the schists, occurring in the southward


R. XVII W.
R. XVI W.
T. 59 N.
T. 58 N.
T. 57 N.
VIRGINIA
EVELETH
DAVIS
WEIMER
Mc KINLEY
JONES
BIWABIK
MERRITT
Pike River
Embarrass Lake
Embarrass River
Wynne L.
Crooked Lake
Cedar Island Lake
1390
Esquagama Lake
Lake Robbins
Forbes L.
Otter River
St. Louis River
Miller
Road
D. & I. R. R.
D. M. & N.
VIRGINIA BR. D. M. & N. R. R.
BIWABIK BR.
WESTERN MESABA BR.
R. R.
GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA
VIRGINIA PLATE
BY N H WINCHELL
Contour Lines
Explanation
Modified drift
Glacial drift
Black slates
Taconic
Archean
Mica schist
Railroads
Wagonroads
Fifty foot contours
Hundred foot contours

spur of the Archean, show the underlying, widespread prevalence of the granitic rock when in a molten condition, and indicate that the Giant's range of granite is something more than a single dike-like intrusion. It is rather of the nature of a result of extended dynamic action, resulting in widespread transformation of the rocks, the granite being, presumably, the extreme product of such action.

The spur of the Archean, already mentioned, therefore existed from the date of the activity of the granite as an intrusive. It is probable that originally the iron-bearing strata covered this spur with something of an upward swell in the surface. The spur has been uncovered by reason of its greater exposure to glacial and other destructive agents, and this leveling action has thrown the present out-cropping edge of the Animikie far to the south along its flanks.

The direction of this Archean spur is about parallel with two others that are now imperfectly known along the Giant's range, viz., northeast and southwest;* and this is parallel with a system of the grand structural features of the northeastern part of the state—indeed, of the whole state and of the world.† It shows the primordial date at which the embryonic earth began to take on its permanent foldings, for these short spurs of the Giant's range are only offshoots from the greater range which also maintains its general east-northeasterly course.

In the special report on the Mesabi Iron range Mr. J. E. Spurr has supposed that a profound fault line, perhaps two of them, crosses this area, the westerly one lying along the west side of this spur, passing through the region of the principal iron mines at Virginia, this acting as a line of structural and of chemical weakness in the rocks which facilitated the greater accumulation of ore,‡ and the eastern one approximately along the valley of Pike river, so far as that valley lies within the area of this spur. But the data on which he relies for this hypothesis are hardly sufficient, nor are they necessary for the establishment of his principal theme. The known rather erratic and wholly inexplicable distribution of the ore bodies in the taconyte horizon, and even the mapping of the same by Mr. Spurr in secs. 8 and 9, T. 58–17, where the supposed fault line is assumed to be occupied by an unusual accumulation of ore, are sufficient to account for the existence of the taconyte rock in the vicinity of Virginia, at irregular and unexpected horizons; while the supposed fault breccia, which is described at a few hundred paces north, at the Lone Jack (now the Oliver) mine, is probably a part of the basal Cretaceous of the region. This deposit is a somewhat angular or sub-rounded gravel of debris from the rocks of the region, but at the Lone Jack mine it is naturally almost wholly of taconyte, in the main converted to ore. It occasionally shows an indistinct, nearly horizontal

* Grand Rapids plate (No. 71); Partridge River plate (No. 76).

† A. WINCHELL. The Diagonal System in the Physical Features of Michigan. *Amer. Jour. Sci.* (iii), vi, 36, 1873. J. D. DANA. *Manual of Geology.* First Edition, p. 30, 1864; and subsequent editions.

‡ J. E. SPURR. The iron-bearing rocks of the Mesabi range. *Bulletin x*, pp. 17–22, 1894.

stratification. The pebbles are rather soft, and much of their angularity is due to subsequent breaking along the joints which preëxisted in the taconyte. But many of them are wholly rounded and smooth, shining with the black irony coating peculiar to the irony balls that lie on the western plains, or that have been subject to long repeated wet and dry along the lower reaches of the Mississippi beyond the drift latitudes. From about a quart of this iron gravel, after washing, there were selected easily six stones of quartz and granite. These characters certainly remove it from the category of fault breccia, and rather strongly ally it with the Cretaceous which is known to occur about a mile and a half further northwest. The irregularity, therefore, which throws the strike of the iron-bearing strata so far to the south had its origin and date in pre-Taconic time, and not since the formation of the Animikie. It might still have been the cause of locally greater accumulation of iron ore at the Virginia locality. For instance, both before and since the Cretaceous there was a superficial gathering of water in the Virginia valley. The elevated Archean to the north and that to the southeast formed a col in which surface drainage gathered, opening toward the southwest, and from which, as now, small streams carried away the mineralized waters, leaving as residua the leached rocks of the taconyte in their various forms, and the ore bodies. The little stream at Eveleth, passing through the Adams ore body, indicates the same relations and the same cause for the greater production of ore at that place. The ore bodies at Biwabik and McKinley are also in the lines of the courses of streams at the present time, and these little valleys are probably near the lines of pre-Cretaceous drainage, which served the same purposes as those of Virginia and at Eveleth. Other present streams are probably of post-Glacial date, and are determined by the posé of the drift. This relation of present drainage to the ore bodies is significant, and suggests the propriety of thorough exploration along other valleys where ore is not yet discovered. Of course, in the case of a merely post-Glacial valley but little or no ore could be expected to have been generated. It would be only in valleys that had a pre-Glacial existence, and in which post-Glacial streams have been continued.

The subdivisions of the Archean. It has not been possible to give a careful study to the Archean along the Giant's range crossing the plates of the western Mesabi range. The determination of the subdivisions of the Archean was made out further east, since the field-work was completed in this area, and it would be necessary to review the Giant's range with some care, to warrant positive assignment of its parts to the subdivisions known further east. However, Mr. Grant made some observations at a series of rock-cuts within a mile east of Mariska, *i. e.*, in secs. 15 and 22, T. 58–17, along the Duluth and Iron Range railroad, which seem to show the separate existence of the Upper Keewatin, the Lower Keewatin and the intrusive granites, all earlier and unconformable with the ore formation of the Animikie.

The eastern cut is perhaps 100 paces in length. The rock is greenstone, fine-grained, roughly schistose, and in places almost slaty. These structures are about vertical and strike N. 45° E. (mag.) In places the rock has fragments and changes of color almost like itself. In other places it is perfectly massive except for the schistose structure, with no appearance of bedding (No. 1091G). But on examining this cut further, and on going on top of the rock where the weathered and glaciated surface is exposed, the rock is seen in many places to be a regular conglomerate. This character comes out especially at the east end of the cut, on account of the greater number of the boulders and because of less similarity to the matrix. At and near the east end of the cut the conglomerate is distinct. The pebbles are well rounded and are often drawn out in the direction of the schistosity; and there is some faint evidence of bedding which runs with the schistosity. The pebbles are of all sizes up to a foot across, but commonly are an inch to three inches. There are various sorts, the following being especially noted: (1) Coarse granite, like the Saganaga granite; (2) Finer gray to pinkish granite; (3) Quartz porphyry; (4) Red, black and gray flint; (5) Graywacke, black slate; (6) Red, porphyritic rock; (7) Several varieties of dioryte-like rock; (8) Quartzless porphyry.

Just south of the track, and about 150 paces west of the above cut, is a knoll of rock, which, where examined, is a gray granite or quartz porphyry, even resembling somewhat the recomposed granite that lies on the real granite at Saganaga lake (No. 1093G). It is probably, however, an igneous rock, but whether older than the above conglomerate cannot be stated, although probably older.

One-fourth mile further west is a long cut in black to gray slaty argillyte (No. 1094G), and graywacke (No. 1095G), the distinct slaty structure being about vertical and striking N. 80° E. (mag.). The bedding at the cut is about with the cleavage, but elsewhere the rock shows much folding, and the slate layers are broken and twisted and enclosed in the graywacke. Most of the fragments in the rock seem to be referable to fractured and sheared slate, but one distinct fragment is of fine-grained dioryte.

About a fourth mile east of Mariska station is another cut. Here the rock is a slate and graywacke similar to the last, with a cleavage strike N. 50° to 65° E., nearly vertical, and bedding agreeing in general with the cleavage. Appearing in irregular masses in the slate, and in sharp contact with it, is a gray porphyritic rock (No. 1096G). The contact is usually along the strike, but in one place runs directly across it. The feldspar phenocrysts appear distinctly only on old fractures. At this cut is also a considerable amount of rock of No. 1097G, which appears to be part of the graywacke-slate formation, but which closely resembles, except for the paucity of phenocrysts, the porphyry (No. 1096G). These both contain, like the argillyte and graywacke, a considerable amount of pyrite in scattered crystals, causing the rock to

weather red. In this, and in the different color of weathering, these rocks differ from rock No. 1093G, which weathers smooth and nearly white.

A provisional interpretation may be made of this series, by assigning the graywacke and slate, and the associated conglomerate, to the base of the Upper Keewatin as described in the Lake county chapter, and the rock No. 1093G, to an early intrusive, belonging in the Lower Keewatin. The pebbles in the conglomerate at least show what formations preceded the conglomerate, and will not allow the assignment of this series to the Lower Keewatin, so far as known, but at the same time show that the Lower Keewatin was present in the vicinity to furnish those pebbles. A similar conglomerate occurs further east, and is described in connection with the Dunka River plate.

The Animikie strata in this area show certain other irregularities. There is a small isolated area of quartzyte and taconyte well to the north, forming a knoll that rises to 1,850 feet above the sea, or within 100 feet as high as the highest part of the Archean spur. This is at the base of the Archean spur (sec. 36, T. 59–17), and detached about two miles from other similar rock. It shows that at one time the Animikie strata must have been continuous over the intervening area of Archean, and hence over the whole spur.

There is another, smaller, upward swell of the Animikie strata further east, probably dependent on another Archean spur, from which the Animikie has not yet been denuded, viz., in sec. 4, T. 58–16. The quartzyte and taconyte here swell up through the slates which, as represented by Mr. Spurr, extend entirely round them to the north, although actually overlying them, forming a small synclinal between the Keewatin on the north and the basal quartzyte on the south.

In other places, where the quartzyte is known to exist, it is also similarly enveloped by the later taconyte. If this be not due to the same cause, it may be explained on the supposition that, after the deposition of the quartzyte, it was buried by the later taconyte by the subsidence of the land area, thus bringing the taconyte instead of the quartzyte into contact with the Archean, as represented by Mr. Spurr's maps, all along this line of superposition on plate 75. Along with this overlap of the taconyte, covering the line of strike of quartzyte, there are still such irregularities that it is necessary either to suppose local later folding of the Animikie, or inequalities of the surface of the underlying Archean. It is Mr. Spurr's opinion that the overlap is due to subsidence immediately after the formation of the quartzyte, and that the isolated quartzyte areas, enveloped by the taconyte or by the black slates and the taconyte, are due to later folding.

[*Note.* Later examinations made by Dr. Grant and Mr. J. U. Sebenius in the fall of 1898, for the purpose of correcting the general map of the Mesabi range, do

not bear out the hypothesis of the subsidence of the region immediately after the formation of the quartzyte, but the quartzyte, so far as could be ascertained, holds its own place, geographically and stratigraphically, the taconyte lying always above it. It is not impossible that some local folding, and subsequent degradation of the surface, may cause taconyte to lie to the north of some outcrops of quartzyte, but such could not be verified.]

The Pokegama quartzyte itself is a nearly pure complex of quartz grains, but when fine grained it is seen, under the microscope, to embrace a few fragments of striated feldspar. When fine, its grains are angular. If it be coarser, it is more permeable to the downward flow of silica- or iron-bearing water, and it becomes cemented by those substances (Nos. 16S and 43S). There are some instances in which quartz grains, of the same appearance as those of the Pokegama quartzyte, are found sparingly in the taconyte horizon (Nos. 41S and 161S). In one instance the Pokegama quartzyte (No. 12S) is so charged with hematite that it might be taken for lean ore, and the loosened, light-colored grit alongside does not correct, but rather confirms, the impression that the rock is one of the phases of the taconyte. It is to be noted as a peculiar fact that the secondary silica which cements the Pokegama quartz grains (Nos. 43S, 1633) is sometimes of multiple orientation, like that which originates in the decay of the glauconite of the taconyte and is deposited at once. In many cases of the secondary growth of quartz grains, the rims of growth extinguish with the original grains as was fully brought out by Irving and Van Hise,* and later by Calvin,† and that is the case in some instances in the Pokegama quartzyte of the Mesabi Iron range (No. 15S). Sections made from specimens collected at Prairie River falls show the secondary silica in optical agreement with the grains (Nos. 1521, 256H, 257H, 261H and 259H), as stated by Irving and Van Hise.‡ It is quite likely that when the supply of secondary silica was rapid it crystallized from many points, in non-agreement with the original grains, and when slow it was oriented with them.

The exact stratigraphic relation of the quartzyte to the taconyte is still an unsettled question. It seems in most places to lie regularly below all the taconyte, especially when it is coarse and fragmental. In other cases it is in the midst of the taconyte, at least above a stratum of jaspilitic silica. This is particularly the case when it is fine-grained (Nos. 1632 and 1640). The quartz then is entirely angular, and embraces also angular grains of microcline and of other feldspars, and is perhaps wholly a secondary rock. The quartz grains interlock compactly, and exhibit no

*R. D. Irving and C. R. Van Hise. On the secondary enlargements of mineral fragments in certain rocks. *Bulletin viii, U. S. G. S.*, 1884.

†S. Calvin. On a new horizon and some new localities for friable sandstone in which the grains are enlarged by secondary deposition of silica in optical continuity with the original nucleus. *Am. Geol.* xiii, 225, 1894.

‡ *Op. cit.* p. 35. and plate IV.

rounded contours referable to fragmental origin. The thickness of this quartzyte is usually not over fifty feet, and is sometimes much less.

Limestone. There is a thickness of very calcareous rock, amounting to ten to fifty feet, according to Mr. Spurr (Nos. 53S, 76S), which lies above the taconyte, which seems to have had, in the main, a fragmental origin, but in some places this calcareous horizon is not identifiable. Instead of it the taconyte rock, more or less flinty, graduates into the black slate with numerous thin alternations, the irony mineral being siderite, as seen south of Virginia (rocks Nos. 1087G to 1090G). This calcareous rock is difficult to distinguish from some parts of the black slates. It is irregularly striped and banded with light and dark gray, like a rock having "false stratification." Its calcareous character apparently fades out gradually upward, and sometimes is hardly discoverable. It is found characteristically on the south side of the road between Virginia and Mountain Iron, in N. W. ¼ N. E. ¼ sec. 7, T. 58–17. This rock is sometimes much altered and ferrated, and is thus involved with the iron ores of the taconyte horizon. Thin as it is, it seems to be nearly continuous over most of the western Mesabi.

The Cretaceous was discovered some years ago in test-pitting in search for ore.* Its thickness at no point was ascertained, but it was penetrated about 100 feet by a churn drill. It varies from coarse conglomerate to shale. The conglomerate is at the base and takes on the characters of the underlying formation, and the shale is green. In some places the Cretaceous contains numerous pieces of wood (No. 104S), and lignitic beds have been encountered (No. 88S). The following fossil genera were identified in Cretaceous from the Mesabi range, by Dr. C. A. White: *Ostrea, Inoceramus, Modiola, Pinna, Yoldia* (?) *Trigonarca, Actæon, Trochus* (?) *and Fasciolaria.*

"*The Yoldia* (?) referred to is much like the *Y. microdonta* of Meek and Hayden, reported to have come from the Dakota group of Kansas. The *Inoceramus* cannot be distinguished from the *I. fragilis* of Hall and Meek. This is a characteristic species of the Colorado formation. For this reason, and because that formation is known to be represented in other localities in Minnesota, I think there is little, if any, reason to doubt that the deposit from which you obtained these fossils represents a portion of the Colorada formation as it is developed in the great interior part of the continent." *White.*†

The peculiar "gravel ore" found at the Lone Jack mine (Nos. 1699 and 1793), and at the mines next west, is a form of the Cretaceous conglomerate determined by the rapid disintegration and supply of taconyte gravel during the prevalence of the Cretaceous ocean. "It exhibits every feature of a promiscuous fragmentary accumulation. Some of it is completely made up of ore like that of the region, but of

*H. V. Winchell. Note on Cretaceous in northern Minnesota. *Am. Geol.* xii, 1893, p. 220.
† *Op. cit.*, p. 221.

rather low grade, and some of it is apparently derived from a rock but little affected by ferric oxide. It seems to vary exactly as the rock of the country does, that is, it is 'lean' or not, and its different constituents can be referred entirely to the country rock adjacent. The further phenomena of this 'gorge' will only be revealed by the mining operations that are sure to follow. At the present time this gravel is simply overlain by the common till and graduates rather abruptly upward into an irony till, and then into gray till. The pebbles are cemented together by a coating of ferric oxide deposited on them since they were placed in their present position, indicating the later supply of some water in large amount, capable of parting with iron oxide. Some of the pebbles have an irony crust harder than the interior, and from the crust toward the centre there is an increase of coarseness of texture, even becoming somewhat spongy, indicating some progressive change from the circumference toward the centre, the whole pebble, however, becoming good bessemer hematite, but such pebbles are not common. The great mass of the gravel, some of it being coarse as walnuts, consists simply of very irony rock of some sort, of very uniform grade throughout. It does not appear that the gravel has become ferruginated to any great degree since its deposition as gravel. The ferruginous surface film is nothing more than such as might be found on any exposed surface over which the waters of this region might pass."* Later than the formation of this black film a coating of white silica has been formed in the cavities of this conglomerate (No. 1793), and this then forms its strongest cementing bond. This is entirely pure and unstained by hematite. That this is a transported gravel and not a breccia is shown not only by the foregoing characters, but by the occasional occurrence, as already stated, of pebbles of quartz and of granite, even in that portion at the Lone Jack mine which is thrown out from the pits. This conglomerate in other places contains but very little iron ore, and has a characteristic green color (Nos. 61S, 86S and 87S), and is also sometimes indistinctly stratified horizontally.

The principal mines of this area are the following: Biwabik, Mesabi Mountain, Hale, Cincinnati, Oliver, Lone Jack, Fayal, Vega, Adams, Franklin, Ohio, Auburn, Norman, Minnewas, Commodore, Lowmore, Genoa, McKinley, Elba, Sparta, Duluth, Canton.

The Biwabik mine was the first important mine in the area of this plate. It embraces the N. W. $\frac{1}{4}$ N. W. $\frac{1}{4}$ sec. 2, N. E. $\frac{1}{4}$ N. E. $\frac{1}{4}$ sec. 3 and the S. E. $\frac{1}{4}$ N. E. $\frac{1}{4}$ sec. 3, in T. 58–16. The ore body is about half a mile in length, nearly a quarter of a mile wide, and has a depth which sometimes reaches 100 feet, and was, at the outset, estimated to contain twenty millions of tons of ore.†

The ore, which has a general southerly dip, with minor east-west folds, is of the quality known as soft bessemer ore, but is partly red and yellow, the largest

* N. H. WINCHELL. *Twenty-first Annual Report*, p. 128.

† The Biwabik Mine: by H. V. WINCHELL and J. T. JONES. *Trans. Am. Inst. Min. Eng.*, February, 1893.

body being of a bluish or bluish-black color. The red hematite is at the bottom of the deposit; and the yellow, which is largely gœthite, is at the top, or occupies large lenses encroaching on the blue ore from above. The Canton mine is celebrated for its yellow ore. Such ore is, as a rule, too high in phosphorus for the bessemer grade.

The Biwabik is an open pit, and required 2,893,333 cubic yards of stripping of drift materials. The ore is excavated and dumped directly on the cars by steam shovel, a method which is elsewhere also extensively employed on the Mesabi range. The tracks are shifted and lowered from time to time as the shovel completes its course through the ore body. The terms of the contract to the lessee require the mining of at least 300,000 tons per annum, and the payment of a royalty to the owners of 50 cents per ton. The ore averages about 63 per cent in iron and .045 in phosphorus.

The Cincinnati mine adjoins the Biwabik on the east, and only differs from the Biwabik in having a large amount of country rock (taconyte) to contend with. Indeed, the Cincinnati mine seems to be essentially on the fringe of the ore body of the Biwabik, and within its territory the normal rock of the formation again prevails. The ore here lies on a sandstone.

One of the trial pits on N. E. ¼ N. W. ¼ sec. 2, T. 58–16, struck an interesting form of the taconyte, which at first was considered as "black slate." It is a form taken on by the taconyte in the process of chemical alteration and transition to ore (No. 1689). The remnants of the rock, nearly unaltered, lying in the products of alteration, give the mass the appearance of a conglomerate or breccia. The isolated masses, sometimes roundish and sometimes quite angular, are all of one sort, *i. e.*, a magnetited, fine, dark-green, nearly black taconyte, which, near the centres of the separate pieces, is grayish. The cement is magnetite, and the rock is nearly black. This rock graduates into the regular taconyte, on one hand, and into magnetite ore on the other. The black slates above are frequently heavy with magnetite, a circumstance which, considered in connection with the production of magnetite in this chemical breccia, indicates that the occurrence of magnetite rather than hematite depends rather on the antecedent physical conditions of the original rock and the slowness of alteration than upon the accident of pressure or folding, or any dynamic force such as the advent of the gabbro.

Another pit at the Cincinnati mine struck a phase of the Pokegama quartzyte not often seen. The rock was greenish and hard, and fine grained, but evidently laminated by sedimentary stratification. It had been mistaken by the superintendent for greenstone. This phase is near the basal conglomerate, and in grain it resembles that seen at Wick's (No. 1632), though its color is usually not pinkish. In the form of boulders it is quite common on the surface, weathering nearly white so as to resemble marble.

In the region of the Cincinnati mine, the rocks being in the main nearly horizontal, or of a uniform gentle dip, the idea of the origin of the ore from a grand change from the taconyte rock is impressed on the observer. The ore alternates intimately with the rock, and occurs as isolated masses in the rock, while *vice versa*, the rock exists as isolated masses in the ore. Such relations could hardly occur without a genetic relation between the two.

At the Duluth mine, just west of the Biwabik, the ore dips south at about 15°. There are some east and west undulations, and an apparent anticline, where the axis runs south, in the north wall.

At McKinley the main ore stratum lies below a body of taconyte and above a sandstone which is sometimes reddened by downward infiltration of iron oxide; but there is also some hematite distributed at higher levels, even in the black slates. Such ore, however, is in smaller amounts, is lean and ochery, although sometimes magnetitic.

At Virginia is an important group of mines, some of them now consolidated under the name Oliver mine. The rock bearing the ore lies on the northwestern slope of an Archean greenstone ridge, which is a spur of the general greenstone area further north, and has a northwest dip, varying from northwest to 12° south of west, amounting to 5° to 15°.

In the early explorations at this point it was found that the taconyte rock lies both under and over bodies of iron ore, and that along with the "pebbly ore," which is probably a basal bed of the Cretaceous, is in places a considerable amount of kaolinic rock which is usually white, or slightly colored in streaks by ferric oxide. This kaolin was regarded by Mr. Spurr as a product of alteration *in situ* of the iron-bearing rocks of the Animikie. But there is reason to ascribe it, in the absence of positive structural observations, to the action of the Cretaceous ocean in gathering together into strata of sedimentary character the residuary clays which resulted from the decay of the older rocks during the long period of surface exposure which preceded the Cretaceous submergence. This is in keeping with known facts from a large area in the southern and western part of the state, where the lower portion of the Cretaceous very frequently embraces large deposits of kaolin, and where the older rocks are visibly seen to be its source. Underneath the "gravel ore" is a stratified layer of kaolinic material, and below the kaolin is soft blue hematite.

There is a large ore body at Virginia, sometimes reaching a thickness of over 100 feet, and it is separated by masses of taconyte, and is plainly a result of alteration of taconyte along favorable lines or in areas of easiest chemical change.*

Along the south and east sides of the Ohio opening,† the dip of the ore is north to north-northwest, from 8° to 20°, varying considerably, and with irregularities. In

* A more detailed description of some of the observed transitions from the rock to the ore is to be seen in *Twenty-First Annual Report*, pp. 131–138.

† The facts respecting the present condition of the mines are from the field notes of DR. GRANT, September, 1898.

one place, for a few feet, the dip is toward the east about 10°. From the north side of the Ohio, two openings of the Oliver, not now worked, can be examined, displaying a pretty constant dip of 20° to the north. East from the Oliver, where the rock has been stripped, there is a general westerly plunge of about 10°, while at the north-east corner of the Oliver stripping, the rock dips about 15° toward the south, and along the north side of this stripping, where much rock is exposed, mostly taconyte, the dip is 8° to 15° south to southwest. The north line, or wall, of the Oliver ore is a breccia of hard ore cemented by soft ore. There are several east-west planes of brecciation from an inch to a foot wide, standing about vertical, the whole zone being perhaps ten feet wide. Between the breccia planes is often hard rock. The ore mined is south of this zone of breccia and abuts abruptly against it. This breccia zone, as a wall, forms the whole north line of the Oliver opening. At the stripping at the east end of the Oliver and near the breccia zone, a little of the ore is seen, and it is crumpled some, but in general dips off to the southwest or south-southwest, at about 15° or 20°. These various and complicated directions of dip can perhaps be explained by referring them to the settling away of the altered taconyte strata from the unaltered masses, the process of alteration being accompanied by a considerable shrinkage in the volume of the rock, and it is possible that the foregoing breccia planes express fracture lines due to the same shrinkage and settling of the iron mass of the Oliver mine away from the more stable taconyte.

At the Norman mine, which is immediately east of the Oliver and connected by stripping, the opening is in ore entirely, showing a south dip of 10° to 25° on the north side, and a north dip on the south side. On the west side the synclinal structure is brought out nicely, the axis of the syncline pitching west at about 10°; and appears to run south of the Oliver and the Ohio. Yet, at the Oliver and the Ohio, there is a general decided synclinal structure which pitches toward the west at a low angle, probably about 10°. The ore is in this synclinal basin, and hard taconyte is on both the north and south, with a comparatively low general dip toward the west. In the syncline itself the dips are steeper and more variable, although maintaining a marked general synclinal structure. In the taconyte rock the dips are both lower and more constant.

In the Adams mine, at Eveleth, the same synclinal structure is apparent in the northern excavation, the width of the basin being, perhaps, 600 feet, and the pitch toward the northwest at about 12°. There are several pillars of rock in the mine, and these pass directly into the ore. Above the ore is yellowish ochre and paint rock, and below it, as revealed by drilling, is quartzyte of a gray color, not banded by ore. In No. 2, of the Adams mine, the same structure is evident, but the pitch of the axis is to the southwest. The two openings are perhaps 700 feet apart, No. 2

south of No. 1, and, according to superintendent Harding, the intervening space is occupied by rock lying nearly flat. In No. 3, of the Adams, as far as work has gone, no syncline has yet been developed, but there is a general southwest dip.

The summit of the hill in sec. 29, T. 58–17, north of Eveleth, consists of taconyte, dipping 3° to 8° toward the southwest. It is hard, gray and banded with iron ore. On the east side it has a precipitous wall 50 feet in hight, and below this the ground slopes off sharply for 50 to 100 feet more. Beyond the valley, toward the east, is another ridge, evidently of greenstone, but no outcrops were seen below the taconyte cliff after hasty examination. The aspect of this wall of taconyte is similar to the vertical Animikie scarps in the region of Gunflint lake.

The Fayal mine is half a mile or more east of the Eveleth, and shows some interesting facts. Southwest from the mine proper, near the southwest corner of the S. E. ¼ N. E. ¼ sec. 6, T. 57–17, some stripping has been done, and a body of black ore, soft and considerably broken up, has been encountered. Below this ore is drift, which also surrounds it. Near the bottom large granite boulders are seen in the ore. According to Mr. Hoveland, the engineer of the mine, the ore is of high grade, and between it and the rock below is another sheet of drift thirty or more feet in thickness. This ore mass has nearly all been mined out. The deposit was about 125 feet long east and west, and about fifty feet wide. It was from five to twenty feet thick, and was evidently a mass of ore included in the drift. Two other deposits of this kind are known further south, viz., N. E. ¼ S. E. ¼ sec. 6, T. 57–17, and they are also being mined. The main mine is underground. According to Mr. Hoveland the development is not sufficient, as yet, to show the general structure, but there is a general dip toward the southwest, more steep near the wall of taconyte, and near the horses of taconyte. The rock taconyte also underlies the ore.

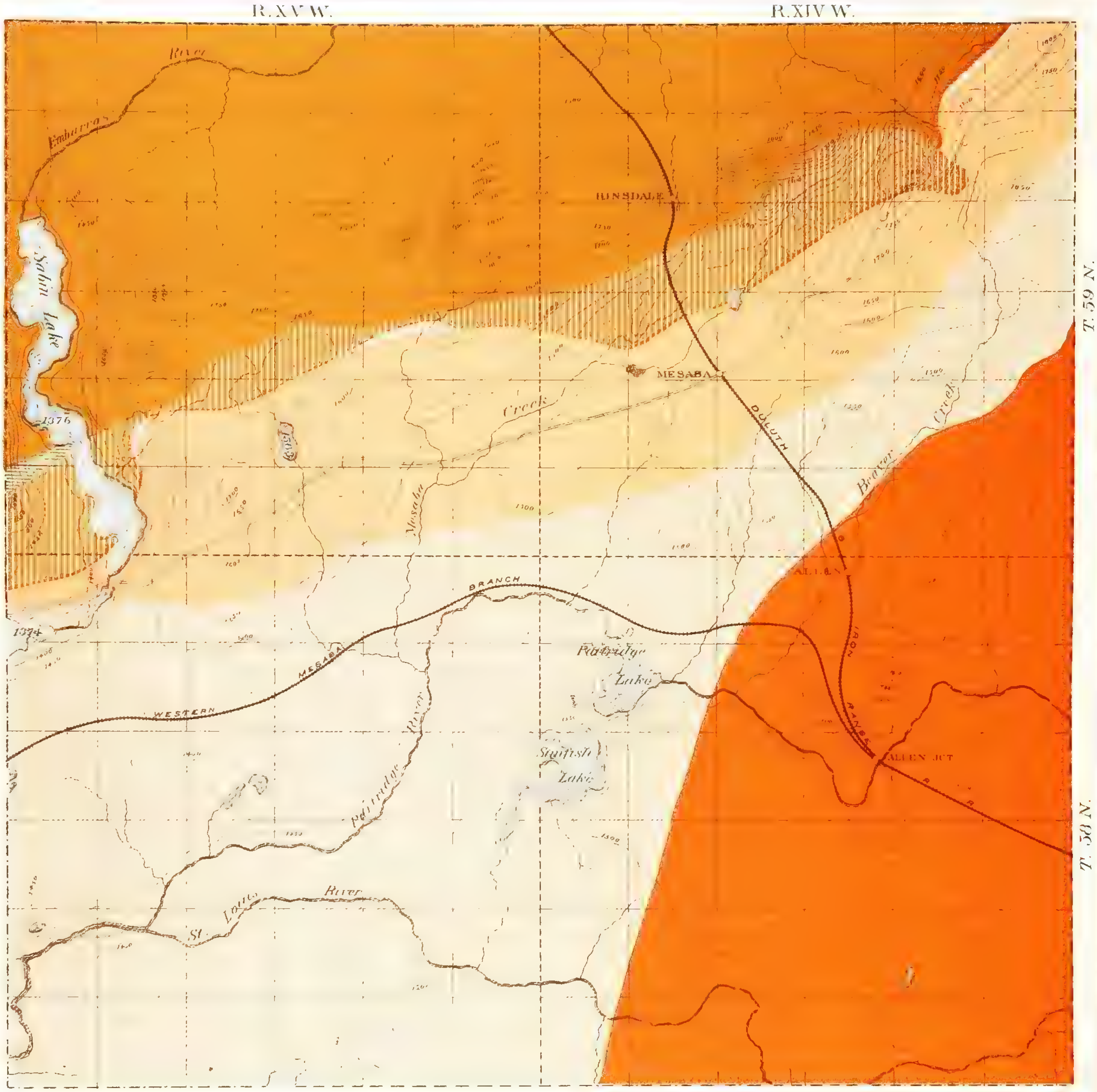
At Sparta (formerly Weimer) are two mines, the Genoa and the Sparta, the former being an underground mine, and the latter a "steam shovel mine." At the latter, along the west wall, are three shallow synclines, all in ore. The east wall has two synclines, separated by a small horse of taconyte. The north wall is in poor ore and rock, and shows a steep dip to the south, from 20° to 45°. These synclines pitch east, or a little south of east, at an angle of 10° to 15°. No rock other than ore is seen in the pit except the horse mentioned above, but on the railroad entering the pit from the south is seen some hard lean taconyte, dipping south-southeast to southeast, at about 10°.

The Auburn is a "milling mine," and the structure here is clearly synclinal, the south side dipping north, and the north side south, with a rather steep pitch (15° or more average) toward the west-northwest. The synclinal structure comes out

nicely on the east side. No rock other than ore is visible. Apparently another syncline occurs next further north, for the dip is again in that direction.

Rock samples from this area. Nos. 10S–56S; 61S; 70S; 76S, 77S; 82S, 83S; 86S–88S; 94S, 95S; 157S–167S; 1688–1707; 2143, 2144; 1070G–1072G; 1080G–1099G.

The characters of some of these stones may be seen by reference to the chapter on the petrographic geology of the northeastern part of the state in vol. v.



GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.

PARTRIDGE RIVER PLATE

BY N. H. WINCHELL.

Contour Lines are shown approximately to every 50 feet above the sea
Figures in Lakes denote altitude above the sea

Explanation

Cabotian	*Gabbro*
Animikie	*Black slates*
	Taconyte
	Quartzyte
Archean	*Keewatin*
	Granite
	Mica schist
	Railroads
	Wagonroads
	Trails
	Fifty foot contours
	Hundred foot contours

CHAPTER XIX.

THE GEOLOGY OF THE PARTRIDGE RIVER PLATE OF THE MESABI IRON RANGE.

(PLATE 76.)

BY N. H. WINCHELL.

This portion of the Mesabi Iron range has not yet afforded any iron ore of economic importance. It was the scene of the first thorough exploration on the Mesabi range after the examination of Prof. A. H. Chester, and after the opening up of the Duluth and Iron Range railroad from Two Harbors to Tower. That road cut the Mesabi Iron range about two and a half miles south of the Giant's range, revealing signs of iron ore. This exposure of hematite, in what was referred to in several of the annual reports as the "red cut," was the cause, through the suggestion of the writer, of the commencement in 1888 of regular testing by machinery at Mesabi station, under the management of Mr. John Mallmann,* though at the expense of the Minnesota Iron company. Immediately a great many other explorers entered on the westward extension of the range, including the Merritt brothers, who were rewarded in the fall of 1890 with the first important discovery of merchantable ore in sufficient quantity on the Mesabi range.†

The Archean granite. The granitic knobs and ridges that cross the northern part of this area‡ possess the most rugged and conspicuous hills of the Giant's range. As further west the descent is more abrupt toward the north than toward the south. The granitic belt here is about six miles wide, the most northern known outcrops being about five miles north of Hinsdale station. There is also an extension of granite, probably as an isolated intrusion, lying south of the crest of the ridge, said to have been encountered by test-pitting at a quarter of a mile north from the Mallmann exploration near Mesaba, or in the S. E. ¼ sec. 20, T. 59–14. The rock is a granite,

*Mr. Mallmann, who had been for several seasons a field assistant on the survey, was somewhat acquainted with the geological structure, and knew the views of the state geologist as to the probable discovery of ore in Minnesota southward from the Vermilion range, and readily fell in with the idea of searching for the equivalent of the Penokee-Gogebic ores in the vicinity of the "red cut." Compare *Thirteenth Annual Report*, p. 23, 1884; *Eighteenth Report*, p. 7, 1889.

†*Bulletin vi*, p. 135, 1891. Compare, also, N. H. WINCHELL. The discovery and development of the iron ores of Minnesota. *Minnesota Historical Society Collections*, vol. viii, p. 25.

‡The following sources afford the data for this description: Report of A. H. CHESTER of examinations in 1875. *Eleventh Annual Report*, pp. 155–167. Examinations and reports of N. H. WINCHELL in 1878 (*Ninth Report*, pp. 107–109); in 1884 (*Thirteenth Report*, pp. 20–24); in 1888 (*Eighteenth Report*, pp. 7, 8); 1890 (*Bulletin vi*, pp. 202–205); also, field notes made in 1892. Examinations and reports of H. V. WINCHELL in 1888 (*Seventeenth Report*, pp. 81–92), and his general report on the Mesabi range (*Twentieth Report*, pp. 111–180, 1891). *Bulletin vi* contains a general description of the Mesabi range and its ores.

sometimes gneissose (Nos. 382H, 1514 and 29M), but in general a true igneous rock. Its color is usually gray, but sometimes pink. It is generally quite coarse-grained, but varies to fine-grained. It has a gray or flesh-colored orthoclase, and coarse quartzes, the latter sometimes of a bluish or lavender color. Biotite and hornblende are occasionally so abundant as to render it a dark rock. Isolated pieces of such dark rock are scattered sparingly in the granite, evidently the result of foreign inclusion. Because of the conversion of the Keewatin into crystalline schists at the contacts of this granite with the greenstones of the Keewatin, it is reasonable to assume that these dark spots in the granite are fragments derived from the Keewatin, metamorphosed by the heat of the granite. Although these spots are frequently rounded, they are not always so, but spread more irregularly.* The rock consists largely of quartz. This is sometimes in large interlocking grains, and sometimes is finely granular. The feldspar is orthoclase, microcline and a very finely polysynthetically twinned plagioclase that is either oligoclase or anorthoclase. There is a singular contrast in the comparative freshness of the feldspars. Some of the large grains are much affected by microscopic scales, probably of muscovite, which have been generated by decay. These scales sometimes pervade the whole grain and sometimes are surrounded by a marginal belt that contains none of them. The microcline, however, is never thus decayed, and appears to be of later generation. The quartzes have been broken by mountain strains, which have formed minute zigzag fractures across some of the larger grains. The biotite and hornblende are fresh.

The rock seems to have been profoundly shattered, but is not much sheared in general, and this action may have been cotemporary either with the intrusion of later granitic dikes or with the gabbro disturbance. The granite as a mass, however, is earlier in date than the gabbro, and is intruded by the gabbro at points further east. It is not yet settled that it followed the Upper Keewatin as to date of origin, and preceded the Animikie, but some part of it appears to have originated in that epoch, which would thus serve to mark a divisional epoch between the Archean age and the Taconic. The reader may consult further discussion of this question in the chapter devoted to the structural geology of northeastern Minnesota (volume v).

The Keewatin. The spur of Keewatin which is represented to occur in T. 59–14, running southwestwardly and reaching into T. 59–15, is somewhat conjectural as to its areal limits, owing to the prevalence of the drift. It is known to outcrop along the south side of the Giant's range from the northeastern corner of this area southwestwardly to S. E. ¼ sec. 17, T. 59–14, one mile south of Hinsdale. It appears in vertical strata in N. E. ¼ sec. 15, T. 59–14, near the north section line. The extension of this

* Compare *Final Report*, vol. i. The Building Stones of Minnesota, pp. 142, 143, where the East St. Cloud granite is stated to show similar dark spots.

Keewatin area southwestwardly, as represented, is based on the distribution of drift masses and on the topography, and cannot, therefore, be relied on with certainty. The northerly extension of the Animikie into sec. 7, T. 59–14, seems also to be a complementary phenomenon in consonance with the supposed southerly spur of the Archean, thus repeating the folding of the Archean mentioned in connection with the Virginia plate (No. 75), from which, later, the removal of the Animikie has been effected by glaciation.*

There are some interesting features connected with the Keewatin in T. 59–14. When Prof. A. H. Chester first explored the iron deposits in section 11, in that town, he noted a peculiarity which he did not explain.†

"Near the centre of section 11 there is a bold outcrop of jaspery hematite, at the foot of which a pit was sunk to considerable depth. At fifteen feet from the surface a layer of black sand was found containing boulders of quite pure hematite. An average sample from these boulders showed 62.17 per cent. of iron, almost the richest ore discovered in the district. Careful search failed to find the ledge from which these boulders came, and they seemed a novelty in a district covered by horizontal layers of magnetite and quartzyte."

It has been found, since, that there are two iron-bearing formations in northeastern Minnesota, and this phenomenon is accounted for by the non-conformable superposition of the later over the earlier. This non-conformity is visible at many places, but there is no other known place at which the formations both contain iron ore at the point of overlap. The jaspery hematite ridge seen by Prof. Chester is a miniature representation of the ridges that contain the Vermilion range ore at Tower and elsewhere; and the structural conditions in general duplicate those which occur at Negaunee, Michigan, where both formations are iron-producing. The existence of rich hematite, seen only as boulders by Chester, in immediate contiguity with this jaspery ridge, certainly indicates the existence of good ore of the Vermilion kind in the near vicinity.‡ This jaspery ridge rises from ten to fifteen feet, running about fifteen rods. It is surrounded by Keewatin greenstone, and the structure is approximately vertical.

Secondly, the Keewatin at this place shows the metamorphosing action of the granitic intrusion of the Giant's range, near which it lies. On two occasions the writer has collected specimens from the small dump of fragments thrown out at the so-called silver-quartz vein, where a little excavation was done under the direction of Prof. Chester. They are represented by rocks Nos. 442 and 1642, and thin sections have been made of both. The former shows, megascopically, a nearly white jaspilyte, similar to much seen at Tower, at the iron mines. The grains are interlocked in such a way that it is plain they are not fragmental in the sense that they are detrital, but their forms are due to chemical growth *in situ*, whatever may

*The westward and southwestward prolongation of this spur was subsequently omitted from the plate showing this area. This was owing to its non-recognition by Drs. Grant and Sebenius when (in October, 1898) the areal limits of the parts of the Mesabi iron-bearing rocks were reviewed with greater care. Hence, if the locality described by Mr. Meeds, N. W. ¼ sec. 18, T. 59-14, be in the Animikie (page 388) it must be in an outlier.

† *Eleventh Annual Report*, pp. 156, 157.

‡ Compare *Bulletin vi*, pp. 203, 204.

have been their origin. It is not known that this is the quartz of the vein. It is probable that vitreous quartz carrying galena first attracted attention, and that this siliceous rock is the country rock of the quartz vein. Rock No. 1642, taken from the same place, is essentially the same as No. 442, but it shows important minor characters. The quartzes lie both loosely and compactly in a matrix that is not clear and transparent like the quartzes themselves, but is clouded with subopaque dust-like particles, in the same manner as the reddish orthoclase which crystallizes out of a rhyolyte, or like the ground mass of a quartz porphyry or a felsyte. This substance does not give a uniaxial interference figure in convergent light, but a curved bar, indicating a biaxial mineral. With the Becke line its refractive index is found to be lower than that of the quartz lying adjacent. In short, it appears that a different composition pervades the ground mass of this rock, while it still has the general aspect of No. 442. It is, it is true, outwardly, a little less harsh, and it has a faint greenish tint within, and pink blotches and veinings are visible on the weathered surface as if it had an orthoclastic element. Further, there are scattering microscopic shreds of chlorite and of mica, and of some other minerals.

Whether these accessory minerals were generated in an original jaspilyte by the action of the granite intrusion, or were formed by the same slow process that takes place in the greenstones of the Keewatin at large, it seems clear that this jaspilyte was not everywhere a pure silica or silica and hematite like the typical jaspilytes that have been described; but while minutely fine quartz grains compose the rock, essentially, and silica probably constitutes over ninety per cent of it, there was a fine admixture of other elements in the original rock. These elements being of the same nature as the prime elements in the regular greenstone, it follows that the jaspilyte and the greenstone were formed cotemporaneously, and shared unequally in the common elements—this unequal sharing in the same essential elements causing, in its extreme, the present contrast that exists between them.*

Thirdly, the rock No. 389H is from the Keewatin in the immediate vicinity. It is granitoid. It has a greenish-gray general matrix, with a uniform fibrous structure, which encloses indistinct crystal forms of feldspar, which, for the most part, are red. These feldspars seem to fade out in the fine siliceous rock surrounding them. Yet, in other cases, there are distinct striated feldspar crystals. The rock outwardly presents such an appearance that it suggests the idea that it is only a more advanced stage of the alteration commenced in No. 1642, in a rock of somewhat different composition, and if that be the case, the alteration is, as seems most reasonable, an example of crystallization through the action of the granitic intrusion on the Keewatin. In this case the result is not a mica schist nor a hornblende schist,

*This alliance of the jaspilyte with the greenstone through gradations from one to the other was discussed, from other specimens, in *Bulletin vi*, 1890 [1891], p. 80.

but a gray, imperfect gneiss. The metamorphism was hence rather regional than contact metamorphism.

In thin section, this rock is seen to consist largely of a much altered feldspar, in which are many scales of muscovite. There has been deposited in some of the old grains, a fresh feldspar, which is near oligoclase, judging from the very small extinction angle in a section perpendicular to the axis (n_g). Many roundish, fine grains of fresh quartz are also scattered throughout the slide. Some hornblende and some chlorite, with a little biotite, and apparently a few grains of sphene can also be determined.

The quartzyte and the taconyte. The relation of these two forms of the basal part of the Animikie to each other structurally is uncertain. There are places where there is a considerable thickness of distinctly fragmental quartzyte, grading into a conglomerate containing much coarse debris from the underlying granite (Nos. 364H and 366H), and there are others where the very bottom beds are taconitic and ferruginous. In one case (No. 22M) the basal, dark conglomerate, carrying coarse quartzes, is also charged with magnetite and red jasper, the latter being of the taconyte variety and lying conformably in the conglomerate as one of its constituent parts, and not of detrital origin. But in still other places there is a large development of the gray taconyte, varying to lean hematite, and to magnetite, which is free, or nearly free, from mechanical debris, all its grains having resulted from the chemical transformations which belong to the generation of the ores of the Mesabi range. Judging from the facts that are presented within the area of this plate, the taconyte and the basal quartzyte are closely associated, and they even blend in one stratum in some places. It is probable, however, that as a general rule the fragmental quartzyte and the conglomeratic characters prevail at the bottom of the series, and that it is only rarely that the taconyte accumulated at the same time and place, while off shore further the sediment was cotemporaneously of glauconitic greensand only, the quartzyte and the taconyte thus being essentially cotemporaneous. This uncertainty is in part ascribable to the nature of the field notes. There are no less than four different rocks which have been denominated quartzyte, and supposed to belong to the same horizon, viz.: (1) The true basal granular quartzyte of the base of the Animikie; (2) The chemical quartzyte which is brown or gray, and very fine-grained, evidently a stratum in some places of considerable thickness and extent, found within the taconyte horizon; (3) The gray taconyte itself; and (4) The siliceous rock Nos. 442 and 1642, which is a nearly white jaspilyte belonging in the Keewatin. This variety in the nature of the quartzyte, which has been observed along the northern strike of the Animikie, is not confined to the area of this plate, and is partly to be explained by a confusion of the Keewatin jaspilyte and muscovadyte with the Animikie ores.

There is one other important fact connected with the Animikie, or what has been assumed to be of the Animikie in the field notes, which has yet to be noted, since the strata referred to seem not to belong to the horizon of Animikie. Mr. Meeds has given a description and diagram of an exploration for iron in N. W. $\frac{1}{4}$ sec. 18, T. 59–14, near the granite range. A shaft was sunk twenty feet, beginning in the horizon of the ore and taconyte, passed through the coarsely fragmental rocks of the bottom of the Animikie (Nos. 22M and 27M), and entered a greenish, more soft and siliceous thin-bedded rock which is very different from anything known in the Animikie. The general dip of the whole is to the northeast and east, but the taconyte also dips in the immediate vicinity toward the southeast. In the shaft above the conglomerate, several feet of iron ore and characteristic Mesabi hard taconyte were passed through, so that there is no doubt that the shaft was at the base of the Animikie, or in an outlier of the Animikie. Mr. Meeds states that there is a general agreement in the dip of the rock below the conglomerate and that above it, but that there is some variation in dip, even in the rock pierced by the shaft, is evident from his allusion to some "change in the dip," which is referred by him to a crumpling in the shaly rock (No. 28M).

It is quite certain that this greenish rock, although it has a general conformity in dip with the iron ore bed and with the immediately overlying conglomerate, does not belong to the Animikie. This thin-bedded, greenish, but rather siliceous, rock occurs in other places, further west, just to the north of the basal quartzyte of the Animikie, and it has, in some cases, been considered as a part of the Animikie. The writer so reported it, where seen north of the Cincinnati mine, although there recognized as lying below the coarse quartzyte (twenty-first report, pages 124, 125, No. 5 of the "principles" stated). Further east it has not been encountered, but the Keewatin rock is distinctly green, vertical, and much less siliceous, except when it holds lodes of jaspilyte, in which case the whole environment and structure are different from this siliceous softer green rock.

The bearings of this peculiar structural fact on the systematic geology of the northeastern part of the state are discussed in another chapter. In short, it seems that this underlying green fragmental rock may develop southerly into the formation in part, which occurs at Thomson, having a near conformity with the Animikie, and that, with the Animikie, it is there involved with the ridges and synclinals described in connection with the Carlton plate. The two would be as indistinguishable as they are on the Mesabi Iron range.

Again, this rock resembles, lithologically, the rock which occurs below the basal quartzyte at the Aurora mine in Wisconsin (sixteenth report, page 58), and which is cut and enclosed by granite a short distance to the south of that mine, and it occu-

pies the same relation to the quartzyte and the Penokee ore (see figure on page 58, op. cit.) It is generally considered by the Wisconsin geologists as a part of the Penokee series and is designated "quartz slates." But it appears rather to be a part of an older formation, the bottom of that series being represented by the quartzyte, which occurs immediately to the south of the ore of the Aurora mine (compare the chapter on the Carlton plate).

The black slates of the Animikie are strongly represented in this area, but nothing can be added to descriptions given in connection with plates further east, where Dr. Grant has divided the Animikie into its constituent members. The uppermost member, as seen at the west end of Loon lake, coming into contact with the gabbro, is a very fine-grained, dark quartzyte (Nos. 2062 and 2063). This portion seems to appear in N. E. ¼ S. W. ¼ sec. 9, T. 58-14, along the shores of Partridge river (Nos. 1708 and 387H). It is too thick-bedded and homogeneous for the term *slate*, and is crossed by a series of vertical joints, the general direction of which is about east and west. It is so closely approached by gabbro on nearly all sides that it must have once been covered by it. It is now a fine-grained mica schist, sometimes with cordierite.

The gabbro is finely exposed at Allen and near Allen Junction, as well as at numerous points further east and northeast, in the same town. Boulders of gabbro do not extend more than a mile west of Allen. The grain varies greatly, there being, in irregular seams and blotches, large crystals of augite and of labradorite, which apparently determine the outlines of "boulders of disintegration," into which the rock falls on the rotting of the surrounding portions. It is, hence, in some weathered surfaces, blotched with lighter and darker spots. In some places the rock is greatly rusted by oxide of iron, being heavy with magnetite. It has, in other words, the characters, in some degree, which the gabbro is known to take on when it is in near contact with the sedimentaries. There are, however, here no visible fragments from the adjacent sedimentaries. It is likely, however, according to later studies, that the blotched and bouldery aspect of the gabbro here described is itself due to the prior existence of boulders in a Keewatin greenstone from which the gabbro is supposed to have been derived.

Rock samples. The following rock samples were collected within this area, and their special descriptions are to be seen in connection with the same numbers in the chapter on the petrographic geology, in vol. v, viz.: Nos. 436-442, 1514, 1642 and 1708; 354H-355aH; 376H-384H; 386H-389aH; 391H-393H; 10M-16M; 21M-29M.

CHAPTER XX.

THE GEOLOGY OF THE DUNKA RIVER PLATE OF THE MESABI IRON RANGE.

(PLATE 77.)

BY N. H. WINCHELL.

The first movement to discover the value of the iron ores of the Mesabi range was directed to this area. The deputy United States surveyor (Wieland) had noted the magnetic variation of the needle when T. 60–12 and T. 60–13 were subdivided. A company was organized to conduct preliminary exploration. The work in the field was in charge of Peter Mitchell, who uncovered the ore-bearing beds at numerous places in secs. 19 and 20, T. 60–12, and in sec. 32, T. 60–13, and penetrated the rock by several shallow shafts. This was continued, with interruptions, through two or more seasons by a small party who labored under great disadvantages, having their base of supplies at Beaver bay.* This occurred in 1873-74. Again, on land owned by the same company, an exploration was made by a sub-company known as the Mesabi Syndicate, on sec. 27, T. 60–13, under the management, in the field, of Capt. Wicks.† Besides these, a third attempt was made in S. E. ¼ S. E. ¼ sec. 23, T. 61–12, at the north side of Birch lake, in 1892, by the Spellman Mining company, under the management of W. L. Honnold.‡ None of these resulted favorably. It is by means of these explorations that the officers of the geological survey have obtained a better understanding of the structure of the rocks of the Mesabi range in this area than in some other parts of the eastern Mesabi.

The Archean rocks occupy the northern portion of this area,§ bounded to the south by the overlying base of the Animikie, but to the northeast by the gabbro whose northern line of strike encroaches on all the other formations in succession. The Archean embraces granite of eruptive phases and mica schist (more or less

*This company is still a corporate body, and holds a large tract of land on this part of the Mesabi range. Its president is Alexander Ramsey. St. Paul. It is the oldest iron-mining corporation in the state. V. Minn. Hist. Collections, vol. viii, 37.

†See the *Twenty-first Annual Report*, p. 82.

‡*Twenty-second Annual Report*, p. 166.

§This area has been examined in different parts by the following assistants, as well as by the writer, and partial reports have been rendered and published as follows:

N. H. WINCHELL (and M. E. WADSWORTH), *Fifteenth Annual Report*, pp. 330-341; *Twenty-first Annual Report*, pp. 82–86, H. V. WINCHELL, *Seventeenth Annual Report*, pp. 81–87 and 92–96. U. S. GRANT, *Seventeenth Annual Report*, p. 162. A. H. ELFTMAN, *Twenty-second Annual Report*, pp. 159–170. A. D. MEEDS (field notes of 1893, not reported). A. H. CHESTER, *Eleventh Annual Report*, pp. 156–160.

GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.

DUNKA RIVER PLATE

BY N H WINCHELL

Contour Lines [illegible]

Explanation

Cabotian		*Gabbro*
Animikie		*Black slates*
		Taconyte and quartzyte
Archean		*Granite*
		Wagon roads
		Trails
		Fifty foot contours
		Hundred foot contours

hornblendic), as well as gneiss. The eruptive phase prevails in the ridge known distinctly as the Giant's range, and also in the region of Birch lake, especially on the southern shores (rocks Nos. 357H, 368H, 400H, 963, 964 and 966). Along the northern shore of this lake there is more variation. Here the Archean becomes gneissic, and in the northwestern part of the lake it acquires a darker color from the presence of much mica and hornblende, and in places the acid rock serves as a cementing material for a breccia that now consists of mica schist. The gneissic characters are represented by Nos. 965 and 955, the dark rock by Nos. 972, 973 and 974, and the mica schist breccia by Nos. 958 and 121G. The geognostic relations of these rocks will be found presented in a chapter devoted to the structural geology, and their special composition in that devoted to the petrographic geology. It is only necessary to say at this place that as an eruptive rock the granite is frequently coarsely crystalline, with large carlsbaded orthoclases, with large lavender-colored quartzes, with microcline and with oligoclase. There is also a probability of anorthoclase in this granite. The usual ferro-magnesian minerals are hornblende and biotite.

There is no known outcrop of Keewatin rocks in this area.

The Pokegama quartzyte and the taconyte horizon. It has already been stated in chapters describing plates further west that there is not a constant distinction between the quartzyte and the taconyte. The same holds true in this area; indeed, the taconyte rock is found sometimes lying immediately on the granite (No. 406H), and in other instances the bottom of the Animikie is a conglomerate (No. 372H) with a fine green (glauconitic?) cement.

The exploration of the Syndicate Mining company on sec. 27, T. 60–13, and other sections in the immediate vicinity, afforded the following information:

Section of the iron-bearing rocks.

A number of diamond-drill tests were made of the iron-bearing rocks, one of which gave a thickness of 323 feet, composed as follows, as furnished by Capt. Wicks:

		Feet.
1.	Drift,	6
2.	Black and gray, fine, banded rock, with fine-grained magnetite, the latter being distributed through the whole, and sometimes in beds six or ten inches in thickness (survey No. 1628),	157
3.	"Black slates," a rather massive rock to be named slate, charged with magnetite (survey No. 1629). Closely allied to the last,	70
4.	Gray quartzyte, nearly all silica, but sometimes porous; has round secretions (or concretions, No. 1630A), shaped like the sponge Hindia, about one-quarter to one-half inch in diameter. These are in cavities somewhat larger, but surrounded by a loose siliceous mesh which keeps them in place. This rock also has some non-homogeneous places – angular and rounded masses appearing cut by the diamond drill (survey No. 1630),	20
5.	"Ore." This is a siliceous, fine hematite. The upper part contains some of No. 4, and the lower part is softer and rather less in iron. This lower part gave no core, but washed away with the cuttings through the drill core, suggesting that it may have been soft ore. Capt. Wicks thinks eighteen to twenty feet may be the average thickness of the ore (survey No. 1631),	24
6.	Fine-grained, pinkish-cream colored quartzyte, evidently granular, though very fine (survey No. 1632), - - - - - - - - - -	17

	Feet.
7. Round, "fragmental" quartz grains cemented in a matrix of quartz. The lower portion of this stratum is of crystalline quartz, or at least of less evidently fragmental grains. Some of it also appears like chalcedonic silica. The crystalline portions present faces of fracture one-sixteenth to one-fourth of an inch across, and resemble the quartz seen at Chub lake. It also contains pyrites in streaks and crystals. The transition downward to the next is gradual (survey No. 1633),	15
8. A hard, siliceous greenish rock, which contains many fragmental grains of quartz one-sixteenth to one-eighth of an inch across, some of them of a lavender blue color. While the mass of this is quartz it is colored apparently by fine debris from the earlier Keewatin greenstones of the vicinity, and should be considered the lower portion simply of No. 7. It also embraces rounded pieces from No. 10, and evident crystals of feldspar (survey No. 1634; compare Nos. 1637 and 336H),	10
9. The lower portion of No. 8 becomes coarse and irregular, lighter colored, with pyrite or chalcopyrite, resembling outwardly a coarse granite (survey No. 1635),	1
10. Granite (survey No. 1636), entered	3
Total,	323

A number of other drills also have been made in the same region, and according to the records kept by Capt. Wicks the following data were obtained:

Drill No. 1. S. E. ¼ S. E. ¼ sec. 29, T. 60-13. Drift, eight feet; black slates, thirty-eight feet (No. 3 of drill No. 5, above); gray quartzyte (taconyte horizon), twelve feet (No. 4 of drill No. 5, above); mixed ore (fifty per cent), ten feet (No. 5 of drill No. 5, above); pinkish quartzyte, the lower portion of this had some of the coarser, fragmental quartz, nineteen feet; granite, four feet; total, ninety-one feet.

Drill No. 2. S. E. ¼ N. E. ¼ sec. 28, T. 60-13. Drift seven feet; black slates, fifty-two feet; gray and brown quartz, fifteen feet; dark gray quartz, nine feet (the last two being the taconyte horizon); ore, hard, mixed, twenty-four feet; mixed ore, and brown, "soft stuff," seven feet six inches; soft, green rock, mixed with quartz, conglomeratic, seven feet; granite, four feet three inches; total, 125 feet nine inches.

Drill No. 3. Surface, four feet nine inches; black slates, eighty-one feet; dark, gray quartz, twelve feet; quartz, and a little ore, four feet; quartz, with seams of ore, four feet; quartz and magnetite, nine feet six inches (the last four being the taconyte horizon); soft material and hard ore, nine feet; brown (pinkish) quartzyte, thirty-two feet; white quartz, coarser, eight feet; granite, four feet; total, 168 feet.

Drill No. 4. S. E. ¼ S. E. ¼ sec. 29, T. 60-13. Drift and boulders, nine feet; black slates, thirty-six feet; mixed brown and gray quartzyte (on the horizon of No. 4 of drill No. 5, above), no ore, seventeen feet; brown quartzyte and ore (six feet of ore in the core interbedded with the quartzyte, ore beds, four or five inches), nine feet six inches; hard ore, fourteen feet nine inches; brown rock, soft, containing ore (thirty to forty per cent), two feet nine inches; white fragmental quartzyte (bottom coarser), ten feet; granite, two feet; total, ninety-nine feet.

The foregoing description was taken in the field. On making a more careful microscopic examination of the samples collected the uppermost rock struck by the drill (No. 1628) is found to be charged, in the light-colored portions, with grünerite, though the principal ingredient is fine-grained and indefinite silica. Minute magnetite grains are also dispersed through it, and in the dark bands magnetite is so abundant that the section is wholly opaque. The rock is apparently a part of the taconyte, concentrated and crystallized by the gabbro. The banding, which denotes the relations between the magnetited and the less ferruginous parts, is highly complex and irregular, often oblique, and frequently blending the one into the other, with lenticular portions enclosed.

Rock No. 1629 is the same as No. 1628, but carrying more magnetite. It is not a part of the black slates proper, but is a constituent portion of the iron-bearing member of the Animikie.

No. 1630 is typical silicified taconyte, retaining the rounded outlines of the original glauconitic grains. These outlines are expressed by their marginal accumulation of magnetite, while their interior is almost entirely of secondary quartz. The

intragranular silica is sometimes of the same coarseness of grain as the intergranular, and in that case sometimes these outlines cannot be distinguished, especially in the absence of magnetite particles; but occasionally, and perhaps most frequently, the intergranular silica is coarser. The secretions or balls (No. 1630A) are composed of the same kind of secondary, granular silica as the body of No. 1630. There is occasionally, in No. 1630, a quartz grain that is apparently of fragmental foreign origin subsequently enlarged, but for the most part this rock is non-fragmental.

No. 1631, iron ore, is mostly hematite, but holds some quartz. A few reflecting triangular minute surfaces indicate octahedra of magnetite, and some square ones cubes.

No. 1632 (compare Nos. 1640 and 371H) is a very fine-grained light reddish-gray quartzyte. When fractured fresh and away from long weathering, this rock is bluish or grayish. When seen in large outcrop it is marked by sedimentary banding. It extends through several sections, but it seems to be lacking in some parts of the Mesabi range. It lies below the iron ore and immediately above the more coarse and fragmental quartzyte of No. 1633. Besides quartz, which occurs in angular grains which in some cases show that they have resulted from an enlargement of more rounded grains, but from the most of which such enlargement is wanting, the thin section shows a scattered sprinkling of small irregular grains of a highly refractive and doubly refractive mineral which appears to be epidote. Occasionally a crystal of this mineral appears, which has parallel extinction, being cut in the zone perpendicular to 010. There is a little chlorite, or at least an isotropic substance, scarce, and apparently about the same amount of a plagioclase feldspar. The coloring matter is hematite. A dust of this coats most of the quartz grains, and permeates other grains, while opaque nodules appear, which are composed entirely of it. There is very little in this rock that shows now distinctly, or even indistinctly, a clastic origin, and it may have resulted very largely from the secondary deposition of silica incident to the change that has passed over the taconyte that lies above it. This supposition is also in harmony with the reported non-appearance of this rock at some places, and its being in some way complementary with the ore, since, according to Capt. Wicks, it is found in those drill-sections where no ore, in considerable amount, is found, and is wanting when there is a distinct stratum of good ore. Its greatest known thickness is thirty-two feet. It gradually acquires a fragmental, coarse quartz toward the bottom, and forms a quartzyte (No. 1633) which, with a conglomeratic phase, lies on the granite. This rock forms, most probably, a stratum in the Animikie in the western part of the Mesabi range, not yet identified, for its boulders are strewn along the old county road, sometimes quite numerously, from Mountain Iron to McKinley.

No. 1633 is a granular quartzyte. Between the coarse fragmental quartzes is fine granular quartz, which serves as cement, and cannot be distinguished from the

quartz described in No. 1632, and is accompanied by the same accessory minerals. These minute quartz grains are not oriented in common with the larger grains, except that occasionally several that are in exact contact with the large grains extinguish in harmony with the large grains. This gives the large grains, to some extent, a roughened or toothed margin, as seen between the nicols.

There is here demonstration of the mingling of granular fragmental material with later chemical deposition, and to that extent showing a mingling of the two processes which have been supposed to have characterized two separate parts of the Animikie, viz.: the quartzyte and the taconyte. By reference to the description of rock No. 1633, it appears that quartz grains and glauconite were originally mingled, and that on chemical alteration of the glauconite there resulted the taconyte structure, iron ore, siderite and actinolite.

The rock No. 1634 is really a modification of No. 1633, by the addition of a green element. It is duplicated by No. 366H, and in 1637. There is a fine siliceous cement intimately mingled with the green matrix, and this is sometimes so free from the green element that its minutely granular structure is distinct. The two elements are mixed in all proportions. The coarse quartzes, as in the last, are crossed by lines of fine inclusions. The green element is in scales and plates, and is strongly dichroic, and can hardly be mistaken for glauconite.

Not only is there quartz and "greenstone" debris in this rock, but occasionally a crystal of orthoclase, which by a fortunate direction of fracture can be seen to be a Carlsbad twin. The whole rock, except the cementing and hardening secondary silica, and the iron ore, is evidently the result of abrasion and fragmental distribution of the minerals of the granites, etc., of the Giant's range.

The lower portion of No. 1634, represented by No. 1635, is a conglomerate made up of granitic debris, with considerable alteration and infiltration.

No. 1636 is granite. The feldspar is considerably invaded by lines and blotches of alteration to a kaolinic substance in which are highly polarizing scales resembling muscovite and calcite. Much of the feldspar is triclinic, and some is microcline. The rock shows apatite, pennine, sphene, calcite and isotropic so-called chlorite, as well as the usual amount of quartz.

The above drill-section represents a total thickness of 323 feet. The other drill-sections made in this region afford about the same succession of strata as that above described. The only rock of uncertain thickness is No. 1632, the fine-grained pink quartzyte, which is apparently absent in some places. The whole of the quartzyte is wanting at a short distance east of this locality. A drill-hole sunk in sec. 13, T. 60–13, passed through 190 feet of "jaspery taconyte," banded with ore and resting upon the granite. The bands of ore were five or six inches thick, and the ore was hard, black and nearly always magnetic.

Mr. H. V. Winchell made observations and collected samples from the base of the Animikie at two points within the area of this plate. He found the gradation S. W. $\frac{1}{4}$ sec. 13, T. 60–13, so gradual from the quartzyte to the granite, through a coarse conglomerate into a recomposed granite, that he considered it a transition in which the point of change from the Animikie to the granite could not be designated in the field. His samples (Nos. 366H and 367H) illustrate the same petrographic features as described from the drill-core samples, some being like No. 1637 and others like No. 1635. The difficulty is in establishing in the field the difference between a natural granite, and a recomposed granite. The infiltration of finely crystalline secondary silica into the base of the Animikie has cemented the green debris into a very firm substance, and when this green debris is scant the rock may easily be mistaken for a truly massive crystalline rock, and the easier when, as in this case, the ferro-magnesian minerals in the original rock are much decayed or wholly wanting.

The general and the microscopic characters of the rocks collected at this locality rather indicate that the base of the Animikie here lies on a conglomeratic portion of the Keewatin. The place has not been reëxamined, but from a comparison with facts known elsewhere it appears quite likely that the conglomerate which here seems to grade into a compact uniform granular rock, indistinguishable from the granite, is the basal conglomerate of the Upper Keewatin.

Sometimes this basal conglomerate is composed, not wholly of debris from granite, but in part of quartzyte or jaspilyte from the Keewatin (Nos. 442 and 1642), indicating the existence of that formation, as in the plate area next west (plate 76), also in this. The existence of rock No. 1639, which is a green, rather shaly debris, also implies the occurrence of an abundant source for such sediments.

The calcareous and black slate beds of the Animikie next above the taconyte have afforded but meagre additional information as to their characters within this area. The highest member, which elsewhere consists of gray quartzytes and slates, is observed to become micaceous, constituting a rather massive and imperfect mica schist (No. 8M). This rises in the form of low northeast-southwest ridges at the south side of secs. 35 and 36, T. 60–13, near the north line of the gabbro, and this metamorphism is to be attributed to the action of the gabbro on the Animikie.

This change consists in a complete recrystallization of the fragmental elements of the rock. The quartz is no longer in rounded grains but in limpid interlocking angular ones, embracing poikilitically the biotite. There is occasionally a small grain of some plagioclase, revealed by its twin striation, and there may be more than appear, since, except for the visible striation, it would be difficult to distinguish it from the prevalent quartz. There is also a little muscovite and a few minute grains

of one or two other undetermined minerals. It appears from this that the effect of the gabbro on a fragmental quartzyte of the Animikie is to render it a compactly siliceous crystalline one, in which the original clastic structure, so far as it is evinced in the shapes of the grains, is lost. The nature, and even the structure, of the resultant rock are, however, not those of massive crystalline rocks resulting from the cooling of a molten magma. Outwardly it still shows a banding and a weak schistosity, which are parallel *inter se*, and which probably express the direction of the original sedimentation. The rock is fine-grained and dark gray, sparkling with the fine mica cleavages.

The gabbro, coming from the direction of Duluth, forms a sharp angle with the strike of the Animikie, and as its northern border crosses first its uppermost member (as just noted) and then the iron-bearing taconyte and the quartzyte, it is the cause of very important and interesting transformations. Its direction is not dependent on the strike of the Animikie, for it passes across it entirely and enters on the granites and schists of the Archean. This fact is illustrated in T. 61–12 of this plate, and more fully by the plate next east of this (plate 78).

This contact zone of the gabbro on the Animikie has been the object of some study by the officers of the survey, as well as by others.* The change is a gradual one, increasing in proportion as the distance diminishes between the gabbro and the strike of the strata concerned. The first specimen collected from this altered belt is No. 437, and it is described in Bulletin vi of the Minnesota survey, p. 129. It is there said to be composed exclusively of actinolite and magnetite.† The occurrence of the same amphibole (which is apparently grünerite instead of actinolite for the most part) is known as far west as the iron mines at Virginia and Mountain Iron, where also are traces of magnetite in thin seams. It appears that these two minerals make their appearance in the iron-bearing rocks under very slight provocation, and that they attain their complete display in the area that is most affected by the gabbro. Some of the amphibole crystals are several inches in length. This largest size prevails near the bottom of the formation at the point where the strike of the gabbro intersects that of the iron-bearing rock. They have been found especially in the vicinity of Birch lake and Akeley lake. This rock has been distinctively known in some literature as the "actinolite-magnetite schist belt," especially on the south side of lake Superior, but there is little reason to perpetuate that term, especially as the rock is liable to great variation and is an accidental phase of a well-known belt which is otherwise known as Pewabic quartzyte‡ or

* W. S. BAYLEY. *Nineteenth Annual Report*, 1890, pp. 193–210; *Amer. Jour. Sci.*, (iii), xlvi, 1893, pp. 176–180; *Jour. Geol.*, iii, pp. 1–20, 1895.

† This was several years before the announcement by W. S. Bayley of the "discovery" of actinolite-magnetite schists in the Mesabi range. *Amer. Journal Science* (iii), xlvi, 1893, pp. 176–180. Prof. A. H. Chester had also mentioned the same in *Eleventh Annual Report*, p. 159.

‡ Reasons are given elsewhere (viz., in the chapter devoted to the *structural geology*) for classing the Pewabic quartzyte and its associated minerals in the Keewatin. Compare also the chapter devoted to Lake county. The basal quartzyte of the Animikie, westward from Iron lake, is hence given the name Pokegama quartzyte. The fine actinolite (grünerite) schists seem to prevail in modified Animikie, and the olivine-magnetite-pyroxene schists in the modified Keewatin.

quartzyte and taconyte. It was designated in Bulletin vi "the quartzose, hornblendic (or olivinitic) magnetite group."

Aside from these two minerals which are almost invariably present in the iron-bearing horizon, other minerals are generated, some of which present very interesting and novel petrographic associations. Numerous minerals which usually accompany only the basic eruptives are here combined with the most acid* elements in immediate contact. The amphibole becomes pyroxene, and it is both orthorhombic (enstatite) and monoclinic (diallage), and they are sometimes intergrown (No. 960) in the manner not uncommon for these two minerals, viz.: 010 of the diallage being parallel to 100 of the enstatite,‡ and in this form making large masses. At the same time the diallage is twinned polysynthetically parallel to 001. This twinning is liable to be mistaken for prismatic cleavage of an amphibole seen in thin section cut in the prismatic zone. Lastly, hypersthene frequently embraces the other minerals poikilitically.

Still further, olivine becomes one of the most common minerals. This fact gave occasion to designate the ore as *olivinitic iron ore* in some of the early reports. A piece of this lean ore (No. 960), containing much quartz and olivine, when powdered, will form a jelly in hydrochloric acid, if allowed to stand a few hours. The details of the petrography will be found in vol. v, and need not be given here.

It is sufficient to repeat that these curious associations are all due to the action of the gabbro on jaspilitic lodes in the Keewatin, which, when recrystallized, constitute the Pewabic quartzyte. They are no part of the gabbro proper. They are found to come on gradually as the gabbro is approached,† quartz being always the leading element, in the form of microcrystalline interlocking grains, which are of secondary origin, or as coarse quartz debris from the granite. Microcrystalline quartz, in this case, is not a product of the gabbro intrusion, as that must have existed in the formation in the same manner as it exists further east and at Tower, where the gabbro has not affected it. The glauconitic alteration in the Animikie must have been in part performed before the gabbro, and the products were further altered by intense crystallization. In some places in the Animikie the taconitic structure is preserved (Nos. 1630, 365H), but usually it is destroyed by the concentration of the minerals under the action of the gabbro. The silica then becomes simply a coarse vitreous quartzyte similar to the Pewabic quartzyte. In some places the basal strata of the Animikie seem to have embraced much fine green sediment derived from the greenstones of the Keewatin (No. 1639). It is to be supposed that such debris, when recrystallized, would give rise to minerals like those from which it had been derived.

*Compare H. Hensoldt, *Bulletin vi*, p. 128, 1890.
† *Minéralogie de France et de ses colonies*, vol. i, p. 543.
‡ A. H. Elftman, *Twenty-second Annual Report*, p. 168, 1893.

It is a fact that the appearance of the above mentioned basic minerals, constituting sometimes, in small quantities, a rock (No. 1339) which might be named lherzolyte,* embraced in nodules and narrow streaks in the general quartzose mass, is near the greenstones of the Archean, where the jaspilyte of the Keewatin is embraced in the greenstones, or in their metamorphic representative, the muscovadyte.

The geographic transition from the Pokegama quartzyte, belonging to the Animikie, to the Pewabic, belonging to the Keewatin, takes place not far from Iron lake, near the centre of this area, and as they were originally of similar composition, they give resulting metamorphic rocks, under the gabbro intrusion, which are petrographically difficult to distinguish. They must then be differentiated by general structural relations and by stratigraphic associations. The Pokegama quartzyte usually dips less than 25°, becoming horizontal, and the Pewabic usually more than 75°, becoming vertical. The Pokegama quartzyte is associated with taconitic iron ore, and the Pewabic with jaspilitic. The former ore is not known to be titaniferous; the latter is usually distinctly titaniferous. The Pokegama quartzyte is never associated with the peculiar muscovadyte, but the Pewabic is never without it. The Pokegama quartzyte, with its taconitic companion, is known to be overlain by the black slates of Animikie, and occurs only westward from Iron lake. The Pewabic quartzyte is overlain and underlain invariably by muscovadyte, or by "gabbro" when the alteration was intense, and occurs only eastward from the vicinity of Iron lake.

Rock samples of this area are as follows: Nos. 955–978; 1137–1140; 1627–1641; 1710–1714; 356H–375H; 394H–406H; 115G–123G; 1M–9M.

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* *Bulletin vi*, p. 127.

GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.

GABBRO LAKE PLATE

COMPILED BY U.S. GRANT.

Explanation

Wagonroads
Trails
Fifty foot contours
Hundred foot contours

Archean

Contour Lines

CHAPTER XXI.

THE GEOLOGY OF THE GABBRO LAKE PLATE.*

By U. S. GRANT.

Situation and area. The Gabbro Lake plate is situated on the western side of Lake county (in fact the western tier of sections is in St. Louis county, as the line separating the two counties is the width of this tier of sections east of the west side of range 11W.), north of the centre. On the west, or rather southwest, is the Dunka River plate (plate 77), and on the east the Snowbank Lake plate (plate 79). The Gabbro Lake plate, so called from the lake of that name† near the centre of T. 62–10, includes all of Ts. 61–10, 61-11, 62–10 and 62–11, and the south half of Ts. 63–10 and 63–11, all west of the fourth principal meridian. The area of the plate, inclusive of water surface, is about 184 square miles.

SURFACE FEATURES.

Topography. The surface is rough and hilly, but there are no pronounced hill ranges and no elevations which rise 200 feet above the surrounding country. The plate is not so readily divided into parts which are topographically distinct, as is the case with the Fraser Lake plate and the plates to the east of it. It may be stated, however, (1) That north of White Iron and Farm lakes, and the Kawishiwi river in Ts. 63–11 and 63–10, the hills usually have an east and west trend corresponding to the rock structure; (2) In the granite area, *i. e.*, between the two parts of the Kawishiwi river (the southern part of which is called Birch river), the hills seem to have no general system, thus agreeing with the structureless underlying granite; and (3) In the gabbro area, to the south and east of the south part (Birch river), of the Kawishiwi river, the hills run northeast and southwest, this direction being due

* The area included in this plate has been examined at various times by different parties of the survey, and most of the field notes have been published. The individuals who did the work, the dates of the work, and the places of publication are as follows: N. H. WINCHELL, field work of 1878, *Ninth Annual Report*, pp. 91, 92; field work of 1886, *Fifteenth Annual Report*, pp. 318–333; field work of 1887, *Sixteenth Annual Report*, pp. 111, 112; field work of 1892, not published; field work of 1897, *Twenty-fourth Annual Report*. A. WINCHELL, field work of 1886, *Fifteenth Annual Report*, pp. 58–60, 67–92: field work of 1887. *Sixteenth Annual Report*, pp. 327, 328. M. E. WADSWORTH, field work of 1886, *Fifteenth Annual Report*, pp. 330–332. H. V. WINCHELL, field work of 1888, *Seventeenth Annual Report*, pp. 96, 97. U. S. GRANT, field work of 1888, *Seventeenth Annual Report*, pp. 165, 166, 191, 195, 196; field work of 1891, *Twentieth Annual Report*, pp. 38–59. A. H. ELFTMAN, field work of 1893, published in part in *Twenty-second Annual Report*, pp. 141-180, and *Twenty-third Annual Report*, pp. 224–230. The writer's field work has been largely confined to the northern boundary of the granite in T. 63–10.

† The Chippewa name for this lake is *Kazushkonabika-gamak*, which seems to mean the lake whose shores are of shelving rock, in reference to the gently sloping shores of gabbro.

to the structure of the gabbro, which rock is not only separated into sheets having this strike, but which is also in places separated into bands of somewhat different composition (figures 5 and 6, plate MM). While these three divisions of the configuration of the surface exist, still they are not markedly different from each other, and a traveller passing from one division to another would scarcely notice the change.

Drainage. The Gabbro Lake plate lies in the drainage basin of Hudson bay, and all the drainage passes through Garden lake to Fall lake, the latter of which empties into Basswood (Bassimenan) lake, one of the series of international boundary lakes whose waters flow westward. The stream passing from Garden to Fall lake is about half a mile long and carries the waters not only from this plate, but from most of central Lake county and part of St. Louis county. It is thus a stream of considerable size. Between these two lakes the descent of the river is seventy-one feet, and about thirty-five feet of this is in one fall, known as Kawasachong falls (see figure 1 of plate BB).

Mention has already been made of the two parts of the Kawishiwi* river, which is not truly a river, but a collection of elongated lakes connected by short, rapid streams. In secs. 24, 25, 26 and 27, T. 63-10, is one of these lakes which, like a few others in northeastern Minnesota,† has two outlets, one at the west in section 28, and another at the south in section 26. The water which passes through the former flows westward to Garden lake, while the water from the latter flows southwest through Copeland's lake and Birch river to Birch lake, and then north through White Iron lake to Garden lake. Thus a triangular area of considerable size in the northern part of this plate, which area is nearly all underlain by granite, is an island.

The drift. As in the region adjoining this plate, the drift is thin and rock outcrops are numerous. Comparatively little is known concerning the general drift features in this plate, but the Mesabi or Eleventh terminal moraine probably passes along the southern edge of this plate while the Vermilion or Twelfth morainic is thought to pass through the northern side of the plate in the vicinity of White Iron, Farm and Garden lakes.‡

GEOLOGICAL STRUCTURE.

The Archean. The rocks included in the Archean may be conveniently divided into three groups, as follows: (1) Greenstones and jaspilytes, (2) Mica and quartz-magnetite schists and graywackes, and (3) Granite. The first occupies a belt about a mile wide along the northern side of the plate, the second occurs in a narrow belt just south of the first, and the third occupies the triangular area between the two parts of the Kawishiwi river. They are all referred to the Keewatin.

*It seems that the Chippewa Indians of this part of the state know this stream as the *Mishiwishiwi*; in the reports of the survey it is called the *Kawishiwi*; while to the settlers in this vicinity and to explorers in general it is known as the *Cashaway*.

†Cf. U. S. GRANT: Lakes with two outlets in northeastern Minnesota, *Amer. Geol.*, vol. xix, pp. 407-411, June, 1897.

‡See *Twenty-second Annual Report*, plate I.

FIG. 1. FALLS, OVER GREENSTONE, AT THE OUTLET OF FROG ROCK LAKE, NEAR CENTER OF SEC. 17, T. 65-5 W. (p. 463.)

FIG. 2. BLUEBERRY RAPIDS, OVER GRANITE, ON THE BOUNDARY RIVER, NORTH OF GUNFLINT LAKE, NEAR CENTER OF SEC. 12, T. 65-4 W. (p. 463.)

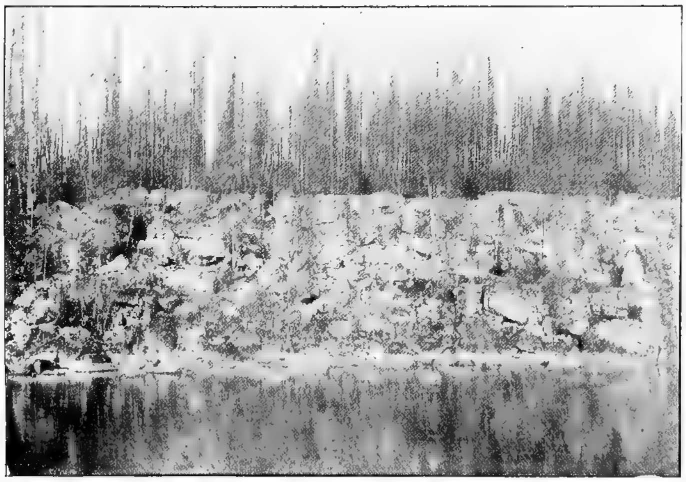

FIG. 3. GRANITE BLUFF SHATTERED BY FROST; SEC. 12, T. 65-4 W. (p. 463.)

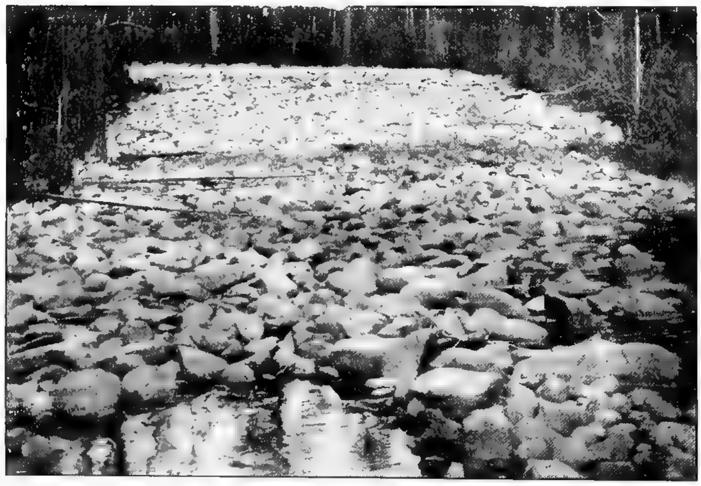

FIG. 4. BOULDER-FILLED CHANNEL; N. W. ¼, SEC. 12, T. 65-4 W. (p. 464.)

FIG. 5. LAYERS OF FINE GRAINED GABBRO, NORTH END OF BASHITANAQUEB LAKE. (pp. 400, 477, 483.)

FIG. 6. A NEARER VIEW OF THE SAME, AS SHOWN IN FIGURE 5. (pp. 400, 477, 483.)

Considerable field work has been done on this plate, and before giving a sketch of the various rocks, it will be best to include some of the detailed observations concerning them. The following notes refer to the Archean rocks principally in T. 63–10.*

Pickerel lake. Pickerel lake† is a small body of water cut by the line between secs. 24 and 25, T. 63–11, and secs. 19 and 30, T. 63–10. The shore, where visited, was found to be made of a more or less massive rock, which in all the reports on this region has been called greenstone or greenstone schist. From the little bay of the Kawishiwi river in the N. E. ¼ S. W. ¼ sec. 25, T. 63–11, a portage leads to the southwest corner of this lake. The southern half of the portage shows angular blocks of mica schist, probably not far removed from their original position, and the northern one-third of the portage is over a ridge of rather massive greenstone. The greenstone extends all along the south shore of the lake. It is shown by No. 305G, which is very dark green and schistose, and occurs just east of the portage, No. 306G, more compact and siliceous, and No. 307G, which was taken from the outlet of the lake in the N. E. ¼ N. W. ¼ sec. 30, T. 63–10. At the east end of the lake, just south of the section line, the rock is green, very tough and massive; it presents the appearance of a consolidated volcanic ash (No. 308G). Only one place (S. W. ¼ S. W. ¼ sec. 19, T. 63–10) on the north shore of the lake was examined; here the rock is a fine-grained massive greenstone (No. 309G).

A section was made from this lake south along a trail, which is almost on the range line, to the Kawishiwi river. Several low ridges were crossed, the general trend of the ridges being east and west. Just south of the lake there are no outcrops seen; but a low ridge of fine-grained compact greenstone (No. 299G) is soon reached. This rock is cut in every direction by minute, branching, yellow and pink veins; it shows no structural lines, but appears perfectly massive. On going farther south the rock becomes schistose, this structure being vertical and running east and west. It is cut by a small dike, four or five feet wide, of a quartzless porphyry (No. 300G). This rock held a small piece of the greenstone, which is very schistose at the dike walls, otherwise not being different from that farther away. The dike runs almost east and west and was traced rather disconnectedly for fifty feet. No. 301G shows the contact of the two rocks. Farther south occur several outcrops of a finely laminated schistose rock (No. 310G) which approaches a mica schist. The laminæ have been twisted considerably in places, but the general strike is east and west, and the dip is vertical. This rock continues nearly to the quarter post, but just before reaching this a rather coarse-grained red syenyte is seen (No. 311G). The hornblende is roughly arranged in elongated spots, thus giving to the rock a decidedly gneissic structure which runs east and west and stands nearly vertical. Associated with this syenyte are small areas of a fine-grained granitic rock (No. 312G). This gneissic syenyte continues about half the distance from the quarter post to the Kawishiwi river, and then assumes a darker, finer-grained aspect (No. 313G), with the hornblende much more abundant than in No. 311G. It now contains fragments, from one inch to several feet in length, of a dark mica schist (No. 314G); these fragments are mostly lens-shaped and their outlines are distinct. The syenyte also holds many veins, up to ten inches across, of a rather fine-grained biotite granite (No. 315G). At this place the gneissic structure in the syenyte, the long axes of the mica schist fragments and the general direction of the granitic veins are northwest and southeast. Mica schist now extends to the river and also occurs on the little point in the S. W. ¼ S. W. ¼ sec. 30, T. 63–10; here, a little back from the shore, is a low ridge of the schist (No. 316G) which strikes 80° W. of N. and dips N. 65°. In it is an irregular vein of very fine granitic rock (No. 317G).

Clearwater lake. Clearwater‡ lake lies almost entirely in sec. 32, T. 63–10, with a small bay projecting into the E. ½ N. E. ¼ sec. 31. Excepting a small area at the northwest corner of the lake, near the portage north to the Kawishiwi river, the shores are composed of reddish syenyte, which is quite constant in character. In the S. W. ¼ N. W. ¼ sec. 32, the syenyte shows an irregular flow structure, which is more evident here than elsewhere on the lake, although seen in several other places. It twists considerably, but stands about vertical, and its general trend is east and west. No. 337G shows this structure very well, although the lines are not usually as near together and as distinct as on this specimen. The syenyte of this lake is well represented by Nos. 338G and 339G, the former coming from the same locality as No. 337G, and the latter from the extreme northern end of the little bay that extends into the S. W. ¼ S. E. ¼ sec. 29. The rock is microscopically a rather coarse-grained aggregate of hornblende and reddish feldspar in about equal amounts.

Where the line between sections 32 and 31 cuts the north shore of the lake the syenyte is seen mixed in with mica schist (see figure 63). The schist is much twisted and the syenyte exhibits the flowage structure, as shown by No. 337G. Most of the syenyte here is of the usual character, but in some areas it is of a finer grain (No. 340G). Just west of this place the syenyte and mica schist are seen in contact. The schist is much disturbed and twisted and the dip and strike could not be accurately determined, but the general trend is a little south of east, with a very high northerly dip. The contact is irregular, but sharp, and is shown in the specimens numbered 341G. No. 342G is the syenyte within a foot of the contact.

At one place on the portage, running northwest from the lake, and in several places on the shore in the E. ½ of N. E. ¼ sec. 32, there is a dark-green rock (No. 343G) which is a coarse-grained aggregate of hornblende with a small variable quantity of feldspar. It presents a very rough, jagged, weathered surface. It is cut by

* *Twentieth Annual Report*, pp. 38–59.

† The Chippewa name for this lake is Gi-nó-ses, which is the word for pickerel.

‡ The Chippewa name is Gawaukamik.

vein-like stringers of reddish syenyte (No. 344G) similar to the ordinary syenyte of the region, by a gray variety (No. 345G) of the same and by a small trap dike (No. 346G). The last is but four inches wide and was traced for fifteen feet; it is probably a very fine-grained diabase.

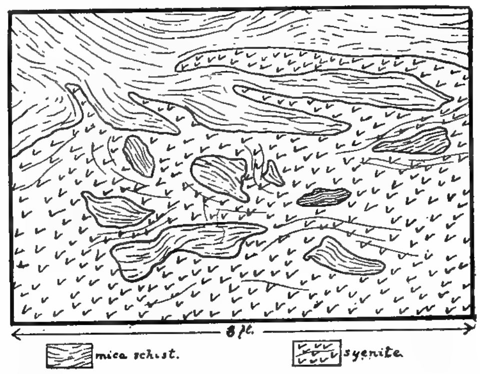

FIG. 63. CONTACT OF SYENYTE AND MICA SCHIST.
N. E. ¼ N. E. ¼ sec. 31, T. 63-10, north shore of Clearwater lake.

South Branch of the Kawishiwi river (T. 63–10 and T. 62–10). Going north from the river nearly on the line between secs. 5 and 6, T. 62–10, the syenyte is seen to be cut by irregular small dikes or branching veins of a hornblende rock (No. 349G) similar to that mentioned above (No. 343G). These veins cut the syenyte in every direction and their outlines are very sharp and distinct, especially on weathered surfaces. The syenyte here varies somewhat, and as a rule is darker colored than that seen elsewhere in this vicinity. The syenyte on the river shore near the above mentioned section line is also somewhat finer grained and darker than is usual (Nos. 350G and 351G). On the north shore of the river in the S. W. ¼ N. W. ¼ sec. 5, T. 62–10, is a rather coarse-grained dioryte (Nos. 352G, 353G and 354G); it is more than half made up of green hornblende, and the feldspar is white or grayish,—the rock thus standing in sharp contrast to the surrounding syenyte. The relations of the two rocks were not seen here, but the dioryte probably is the same as the hornblende vein rocks described above, although in this place the dioryte may possibly represent a basic facies of the syenyte.

No. 355G, from the S. E. ¼ N. E. ¼ sec. 5, T. 62–10, well represents the syenyte in this immediate vicinity. It is a rock of medium grain, reddish in color, and composed of a flesh-colored to reddish feldspar and hornblende; the latter makes up about one-third of the rock. Going south along the river in sections 5, 4 and 9, the syenyte, as a rule, becomes finer grained, and in some places holds biotite instead of hornblende.

At the north end of the portage, N. W. ¼ S. W. ¼ sec. 9, T. 62 10, just at the water's edge, is an outcrop of medium-grained hornblende granite (No. 356G); the quartz makes up about one-fourth of the rock. This is evidently a part of the syenyte of the region, but is the first seen that contains macroscopic quartz grains in any amount. About one-third way across the portage the coarse-grained gray gabbro (No. 357G), common to this region, is seen. This was traced west of the portage to within 200 feet of the syenyte, but low ground with no exposures intervened between the two rocks. Here the syenyte is fine grained and micaceous, as is shown by Nos. 358G and 359G, the former being more properly a biotite granite. The syenyte is cut by small dikes or veins of a fine-grained red aplyte (No. 360G) composed almost entirely of a red feldspar and quartz. The gabbro retained its coarse-grained character as near to the syenyte as it was found.

The east side of the rapids, in S. W. ¼ sec. 9, T. 62–10, was carefully examined in order to study the relations of the syenyte and gabbro, but nothing conclusive was seen. The syenyte here is shown by Nos. 361G and 362G, both rather fine grained and micaceous. Between the syenyte and gabbro were found Nos. 363G and 364G, the former partaking of the characters of the syenyte and containing large quantities of a dark mineral, probably hornblende; the latter is finer grained and very dark in color. There were no continuous exposures connecting the syenyte and gabbro. At the foot of the rapids I found several angular blocks, apparently not far removed from their original position, of a fine-grained purplish rock, probably a porphyryte (No. 365G). Mr. Wood examined the west side of the rapids, but could not find the gabbro and syenyte near each other.

The west shore of the river in secs. 34, 35 and 26, T. 63–10, is made up of the ordinary syenyte, which varies somewhat in the amount of hornblende it contains, as seen in Nos. 366G and 367G. No. 366G is quite dark in color and the hornblende makes up more than one-half of the rock,—this facies, however, is exceptional. No. 367G is much lighter colored and is at least three-fourths composed of feldspar. No. 368G, from the S. W. ¼ of sec. 34, fairly shows the syenyte along this shore; it is composed of flesh-colored to red feldspar and black hornblende, the latter making up perhaps one-third of the rock. This rock is of a medium coarse grain.

North branch of the Kawishiwi river (T. 63–10, and sec. 19, T. 63-9). Mr. Wood went south from the river about on the west line of sec. 31, T. 63–10, for about half a mile. He reported mica schist (No. 318G) all the way, but in a few places, especially just south of the river, a green schistose rock (No. 319G), probably a condition of the greenstone, was seen. From this section line he went northeast to the bay in the S. E. ¼ S. W. ¼ of sec. 30, but saw no rock *in situ* except the mica schist.

The little promontory on the south side of the river in the N. E. ¼ S. W. ¼ sec. 30, is made up of red syenyte (No. 320G). This is a rather coarse-grained rock, and in some places it shows a distinct gneissic arrange-

ment of the feldspar and hornblende. It is cut by a dike of a dark hornblendic rock (No. 321G); this dike is vertical and varies from ten inches to two feet in width; it runs a little south of east and was traced for fifty feet. The west end of the portage across this promontory is in the mica schist, but the line between the schist and syenyte soon crosses the portage and runs a little south of the bay in the S. W. ¼ S. E. ¼ of sec. 30. The two rocks were seen in actual contact just north of the portage; there was no transition from one to the other, the line between them being quite distinct. The syenyte was finer grained and grayer in color near the contact; this is shown by Nos. 322G to 325G, which were taken within a distance of two feet. The last one was touching No. 326G, which is unmistakably part of the mica schist. No. 327G is the mica schist near to the last, and No. 328G represents it a few feet from the syenyte. The line of contact was vertical and rather irregular; the syenyte usually followed the direction of the schistosity, but in some places broke across it for a few inches. On the portage a few loose blocks were seen which showed both rocks in sharp contact (No. 329G); however, it is not certain that these blocks had not been moved some distance.

The west shore of the river in the E. ½ of sec. 30 is almost all syenyte, but about the centre of the shore line some mica schist is seen mixed with the syenyte. The latter extends in vein-like branches into the former and also encloses pieces of it. Mr. Wood went from this place west to the stream that enters the river in the S. E. ¼ N. W. ¼ sec. 30. and reported syenyte all the way. He also found a fine-grained dioryte dike (No. 330G), in the syenyte; this ran north and south, was ten feet in width and was traced for sixty feet. He also reported many inclusions in the syenyte, of which Nos. 331G and 332G are samples; the former is a dark, rather fine-grained dioryte, the latter a fine-grained siliceous schist.

At the rapids in the S. E. ¼ N. E. ¼ sec. 30, the river flows over angular syenyte fragments. On the east shore of the river in the same one-sixteenth section mica schist and syenyte are seen in contact. There is not as sharp a line here between the two rocks as at the above described locality; the change from one to the other occurs within one or two inches; Nos. 333G to 336G represent this change. The first three of these were taken within a distance of three inches.

The point in the N. E. ¼ sec. 26 is made up of the ordinary coarse red syenyte of the region, but on the north side of this point, about the centre of the section, is a dark, rather coarse-grained dioryte (No. 369G). Macroscopically this is seen to consist of hornblende and a white feldspar, the former in larger amount than the latter. Under the microscope the feldspar is seen to be very highly altered, and in only a few places is it fresh enough to show traces of polysynthetic twinning; the hornblende is of the ordinary green variety, and is extensively changed to chlorite and some few flakes of biotite. The relation of this dioryte to the syenyte of the region was not determined, but the impression is that this is a basic facies of the syenyte. The dioryte is cut by a fine-grained trap dike (No. 370G) and also by a light reddish fine-grained granite (No. 371G). The last appears in quite an amount and extends along the south shore of the river as far as the west end of the island in the S. E. ¼ N. W. ¼ sec. 26. A short distance beyond this the dioryte is seen in contact with a fine-grained gray granite (No. 372G), which is probably a part of the same rock as No. 371G. The dioryte here (No. 373G) has both red and white feldspar and seems to be rather intermediate between the ordinary syenyte and the dioryte described above (No. 369G), thus indicating the probable identity of the two rocks. No. 374G shows the two rocks (Nos. 372G and 373G) in contact; the line is very sharp and distinct, but at this place nothing was seen to indicate the relative ages of the two. The dioryte continues along the shore in the S. W. ¼ sec. 26, and in some places becomes lighter colored, as shown by No. 375G. In a westerly facing dioryte cliff (N. W. ¼ S. W. ¼ sec. 26) are three small dikes, about a foot wide, running diagonally up the cliff towards the north. No. 376G was taken from one of these dikes; it is a dark, rather fine-grained rock, composed almost entirely of hornblende.

At the southern end of the bay in S. W. ¼ S. W. ¼ sec. 26 the syenyte again occurs. It is here represented by No. 377G, which has most of its hornblende altered to chlorite. At this place a small piece of finely laminated gneiss (No. 378G) was found enclosed in the syenyte. The western shore in the E. ½ sec. 27 is composed of the syenyte similar to No. 377G.

Just north of the river on the line between secs. 21 and 22 is a low outcrop of aphanitic greenstone (No. 379G). It is much cracked and fissured and shows an indistinct, coarse, schistose structure, which is vertical and runs east and west. Farther north from the lake on the same section line is an outcrop of very massive greenstone (No. 380G), which is of coarser grain and grayer color than that last mentioned. This is seen in contact with a quartz porphyry (No. 381G), which holds a few quartz crystals, many white feldspars and numerous small pyrite grains in a grayish groundmass. The contact line between the two rocks is sharp, stands vertical and runs north and south. Only a small area of the quartz porphyry was exposed; it probably forms a dike in the greenstone. Continuing northward on this section line for about three-quarters of a mile from the river, several ridges of massive greenstone are crossed. No. 382G shows the most massive and coarse-grained condition of this greenstone.

On the north shore of the river, just west of the line between sections 27 and 28, are several outcrops of a fissured greenstone similar to No. 379G. Farther west on the same shore, and just east of the portage, is a large outcrop of a finely laminated graywacke-like rock (No. 383G); it is in some places much coarser grained, as shown by No. 384G. The strike is N. 75° E., and the dip from 75° to 80° S. On the north side of the river and between the portage and the head of the rapids (N. E. ¼ N. E. ¼ sec. 28) a rock similar to the last, except that it is more massive in appearance, is found. Here, on some of the weathered surfaces, an indistinct vertical lamination is seen; this varies somewhat in direction, but the general trend appears to be about 25° E. of N. Nos. 385G and 386G represent the rock at this place. This laminated rock belongs to a fragmental series which is here in contact with syenyte. This series is made up of rocks which are very often graywackes and often mica schists, with all inter-

mediate stages; and there are also some facies that are more like coarse grits, siliceous schists and even sericitic schists. These different facies constantly intergrade. For convenience the term "graywacke-like rock" will be used for the finer-grained and less crystalline rocks of this series. Mica schist and gneiss will be used to refer to parts of the same series which are more highly altered.

A short distance from the east end of the above mentioned portage, rock similar to Nos. 383G and 384G, is found; here the lamination is distinct; the strike is 72° E. of N., and the dip S. 85°. A little further west the syenyte No. 387G occurs. It has a vertical gneissic structure which is very evident on weathered surfaces; this strikes on the average about 70° E. of N., but varies as much as 15° either side of this direction. This syenyte occurs directly in the strike of the last mentioned outcrop of laminated graywacke-like rock.

About half way across the portage is a soft fissile greenstone or greenstone schist (No. 388G). In this is a series of parallel veinings which coincide with the direction of the cleavage planes in the rock; both stand vertical and strike N. 80° E. A few feet south of this the ordinary syenyte is seen. There is almost a continuous exposure between the two rocks, and samples illustrating the change from one to the other were taken. No. 389G, from eight inches south of No. 388G; No. 390G was eight inches further south; then within a foot came No. 391G and No. 392G; two feet further was No. 393G, and three feet from this No. 394G, which grades into the ordinary syenyte represented by No. 387G. The change from the greenstone schist to the syenyte is first noticed by a small amount of red feldspar in the greenstone; the feldspar gradually increases in amount and the green material decreases until the ordinary syenyte is reached. The schistose structure in the greenstone and the gneissic structure in the syenyte are parallel and grade into each other as the two rocks intermingle. One hundred feet north of this place is a low southerly facing bluff of greenstone, much cracked and fissured. On the weathered surfaces it shows a series of reddish, vertical veinings whose average strike is N. 70° E., and almost at right angles to this are two nearly parallel systems of joints which cut the rock into small elongated diamond-shaped areas.* Specimen No. 395G shows this jointing fairly well.

Further west on the portage trail more of the greenstone is seen. Then the syenyte appears again, and beyond this, not more than 200 yards east of the west end of the portage, the graywacke-like rock again appears. It has the distinct lamination seen before and strikes N. 60° E.; the dip varies from 80° towards the north of this line to 70° on the other side. The syenyte occurs on the portage directly in the strike of this rock and not more than 150 yards east of it. The laminated rock is seen in contact with the syenyte, which here lies north of of it, about fifty yards north of the stream. It is here shown by No. 395aG, which has considerable sericitic material developed in it. Eight inches north of this occurs the actual contact between the two rocks; the hand specimens No. 396G show this. The line between the two is distinct, but the syenyte holds considerable of the material of the other rock. Six inches north of this the syenyte is shown by No. 397G; seven inches beyond by No. 398G; eighteen inches from this by No. 399G, and four feet further north it has its usual character and appearance, as shown by No. 400G. At this place the contact was along the strike of the laminated rock, and there is nothing to show their relative ages. The syenyte now extends northward for thirty feet, where it disappears under the soil, as it does just to the west of this place. Boulders of massive greenstone occur just north of the syenyte, but the greenstone is not seen certainly in place until a low ridge of it (No. 401G) is reached fifty feet north of the syenyte.

The high ridge, running east and west through the N. ½ N. W. ¼ sec. 28, is composed of massive greenstone. In places it is cut by irregular branching dikes of gray quartz porphyry. These dikes vary from an inch up to more than a dozen feet across. The principal and largest one runs about east and west along the southern edge of the top of the ridge and varies considerably in width. The contact between the porphyry and the greenstone is sharp, and there is no intermingling of the two rocks. At the contact the greenstone does not appear to be much changed except that it is more broken and fissured. Pieces of the greenstone are included in the dyke. Nos. 402G and 403G represent this porphyry; the former was taken within three inches of the edge of the dike, and the latter about four feet from the edge. This rock has a grayish ground mass in which are imbedded a few quartz grains and numerous flesh-colored and blood-red feldspars. The quartz is more plentiful near the edge of the dike (No. 402G). In places the rock contains minute cavities, apparently formed by the weathering out of certain constituents of the rock.

On going south from the stream into the S. E. ¼ N. W. ¼ sec. 28, the graywacke-like rock is seen showing the characteristic lamination. Soon this rock begins to grow more crystalline, and this character becomes more and more pronounced as one proceeds southward. No. 404G shows this more crystalline facies, but in this the lamination is still distinctly preserved. Interbedded with this are beds of a less crystalline character, as shown by No. 405G, which is very similar to the mica schist found to the west in section 30, already described. Other facies of this rock are shown by Nos. 406G, 407G and 408G, which are all completely crystalline. The first of these is a distinct gneiss, and the latter show no gneissic structure, even on the most favorable weathered surfaces. Macroscopically these three specimens are seen to be composed of quartz, a light-colored feldspar, biotite and some little hornblende. These rocks, while completely crystalline, can in no wise be separated from the less crystalline facies and the graywacke-like rocks already mentioned several times. They are interbedded in bands from one-half inch to two feet in thickness, the more crystalline always in the thicker beds. They seem to grade into each other across the strike, and in some places the less crystalline is replaced along the strike by the more crystalline, the former fading out into the latter. The most crystalline facies contain many black, lens-shaped pieces of black dioryte (No. 409G); these pieces are composed mostly of hornblende with some little

*Compare the diagrams of jointing and schistose structure in the greenstones of the Menominee river, Michigan; *Bullĕtin lxii, U. S. Geol. Survey*, p. 128.

white feldspar. The exposures above described extend south from the stream for a quarter of a mile, and beyond this is low, swampy ground with no exposures. The strike at the most southerly place seen was N. 70° E., and the dip vertical or very steep toward the south.

A narrow belt of syenyte (No. 410G) extends along the north shore of the river in the N. ½ N. E. ¼ sec. 29. Just north of the syenyte is a range of greenstone hills running east and west. In some places the two rocks were seen within fifty feet of each other, but at no place was the junction between them seen. The syenyte rises in a bold bluff at the portage in the W. ½ N. W. ¼ N. E. ¼ sec. 29. About one-quarter of a mile east of this portage the greenstone is cut by an irregular dike of gray quartz porphyry (No. 411G). This dike where examined is three to ten feet wide and has a general east and west direction. It was also seen, but not visited, in the greenstone both east and west of this locality. This dike is probably a westward continuation of that already described from the N. ½ N. W. ¼ sec. 28.

Coming south from the river about on the line between sections 28 and 29, the laminated rock and gneiss similar to that described above (Nos. 404G–408G) are seen in many exposures. About one-third of a mile from the river the syenyte suddenly appears. It was first seen as a belt, 100 feet in width, running parallel with the gneiss which appears on both sides of it. The gneiss preserves its usual character and distinct alternation of different bands clear to the syenyte. No. 420G shows this rock within a few feet of the syenyte. Nos. 421G and 422G come from within three and one inches respectively of the syenyte; the latter is some more coarsely crystallized and contains many distinct hornblende grains and some red feldspar. No. 423G shows the two rocks together; the line between them is quite sharp and distinct. No. 424 is the syenyte just beyond No. 423G; it is quite gneissic in structure. The strike of the gneiss is N. 60° E., and the gneissic structure of the syenyte stands parallel to this; the dip is 5° either side of the vertical. In some places the line between the two rocks, instead of running with the lamination, runs across the strike for a few inches. In other places the syenyte is more completely granitic in structure as shown by No. 425G. A short distance south of this the gneiss is much contorted and is cut by stringers, two to three feet across, of the syenyte; some of these run with the lamination of the gneiss and others cut across it. There is no gradation from the gneiss to the syenyte; the line between the two is clear and sharp. Further south the syenyte becomes the prevailing rock, and in many places it holds lenticular masses of the gneiss.

On the south shore of the river just west of the line between sections 28 and 29 the laminated rock is seen. Still further west, about half way from this section line to the rapids, which are about in the N. W. ¼ N. E. ¼ sec. 29, the syenyte again appears, but less than 200 feet south from the shore it comes in contact with the laminated rock. The junction here is along the strike of the laminated rock and the syenyte was not seen cutting across the strike. The line between the two was distinct and easily seen on weathered surfaces. From the rapids just mentioned west to the east line of section 30 the laminated rock occurs on the south shore, and a high bluff of it is seen just south of the river on this section line. The little bay in the N. E. ¼ N. E. ¼ sec. 30 has syenyte on its south and greenstone on its north shore.

Mr. Wood went south from the river about on the line between sections 29 and 30. He found the laminated rock in place all the way until nearly half a mile from the river, when the syenyte was seen. No. 426G shows the laminated rock, which here approaches a mica schist, and No. 427G is more accurately a mica schist. This latter facies of the rock was that most commonly seen, but that seen nearest the syenyte was more like No. 426G.

The north shore of the river, in the N. ½ N. W. ¼ sec. 29, is made of greenstone, but the syenyte comes in at the water's edge just west of the portage in the eastern edge of this quarter section. I went north from the river on the west line of this section for one-third mile, but found no rock except massive greenstone, of which several exposures were seen. About one-fourth of a mile east of this line and just north of the river the greenstone is cut by a dike of reddish fine-grained rock (No. 428G), resembling a syenyte porphyry. The dike has an east and west direction and was traced for fifty feet. The sides of it were covered by soil, and as far as seen it was not more than ten feet wide.

The point on the south side of the river, in the W. ½ N. W. ¼ N. W. ¼ sec. 27, is made up of the laminated rock* and is well shown by the specimens already described, Nos. 383G to 386G. The strikes varies from N. 30° E. to 45° E., and the dip from 75° to 80° S. E. Along the shore just west of this point the laminæ are much contorted. The point on the north side of the little bay in the same one-sixteenth section is also made of the same rock. The small island in this bay is composed mostly of the syenyte, but the northern side has a little of the laminated rock. Near the syenyte this rock changes, becoming more crystalline and acquiring some reddish feldspar (Nos. 429G, 430G and 431G; but this condition exists only within a few inches of the syenyte,—in fact the syenyte, as shown by No. 432G, is seen within six inches of the above specimens. The junction between the two is easily seen as a pretty distinct line on weathered surfaces. Small pieces of the laminated rock were found in the syenyte; No. 433G is from one of these. On the shore just east of this the syenyte is intimately mixed with the laminated rock; still the line between the two is distinct and the syenyte seems to have enclosed pieces of the other rock. In one place the syenyte holds a small area of a dark compact mica schist (No. 434G), which is really part of the laminated rock, and shows lamination in favorable places. No. 435G shows this rock and the syenyte together; they are marked off from each other by a sharp line.

The laminated rock is again seen on both points of the promontory in the N. E. ¼ N. W. ¼ sec. 27, but the syenyte appears on the western shore of the little bay in this one-sixteenth section, and also on the south and east sides of it. At the southeastern corner of this bay the rock has a decidedly schistose structure, and there

* This is the rock described by N. H. WINCHELL in *Fifteenth Annual Report*, p. 352, under No. 989.

are alternating bands of schistose syenyte (No. 436G), and rock similar to Nos. 429G and 431G, which appears to be an altered condition of the laminated rock; this is shown by Nos. 437G and 438G. These bands of syenyte and Nos. 437G and 438G vary from one inch to one foot in width, and they are parallel to the schistosity of both rocks. This is N. 40° E., and the dip nearly vertical. Nos. 437G and 438G, while still retaining considerable of the sericitic material, have large quantities of reddish feldspar and some hornblende developed in them. Between these bands and almost always running parallel with them, are vein-like forms of a fine-grained pinkish granitic rock (No. 439G), holding flesh-colored feldspar phenocrysts. These veins vary from one to ten inches across, and rapidly change their thickness in a short distance. They are also frequently faulted.

On the north shore of the river in the N. W. ¼ N. W. ¼ sec. 27 the laminated rock is found, and just north of this is a belt of syenyte 150 feet wide, separating this rock from the greenstone. The junction of the syenyte and laminated rock was seen in one place; the phenomena at the contact are the same as those already described under Nos. 395aG to 400G. The line between the two rocks runs parallel with the strike of the laminated rock and is quite easily distinguished. The syenyte is also seen in contact with the greenstone; the change from one rock to the other occupies one or two feet and is essentially the same as that described above under Nos. 388G to 394G. In some places in this vicinity the syenyte, especially when in close proximity to the greenstone, becomes very schistose, as is shown by No. 440G, which is dark colored and shows a decidedly gneissic structure; but generally in this one-sixteenth section the syenyte is dark, massive and chloritic (No. 441G). The syenyte extends along the north shore from this place to the small bay in the S. E. ¼ S. E. ¼ sec. 22. It forms only a narrow belt between the river and the greenstone ridge just north of it. Along this shore the syenyte varies from a massive state, similar to No. 432G, to a more chloritic (No. 441G) and schistose condition (No. 440G).

The island in the middle of the river just north of the west end of the promontory, in the N. E. ¼ N. W. ¼ sec. 27, is composed entirely of the graywacke-like rock. The lamination is very pronounced and the strike is quite constant, being about N. 63° E.; the dip is nearly vertical. This strike would carry the rock into the north shore of the river less than a quarter of a mile east of the island, but there the syenyte is seen and there is no sign of the graywacke-like rock.

On the little bay, in the S. E. ¼ S. E. ¼ sec. 22, the graywacke-like rock is again seen just north of the south line of this section. The lamination is very distinct, and, while varying some, has a general northeasterly strike. A short distance south of this the syenyte appears and extends along the north side and to the end of the point which makes the southern side of this bay. The graywacke-like rock makes up the southern half of this point; it is much twisted and crumpled. Its junction with the syenyte was seen in one place; the line between this (No. 442G) and the syenyte (massive and similar to No. 432G) was distinct. Just at the contact the graywacke-like rock showed distinct lamination in but a few small areas and here it faded out in a short distance. Away from the contact the lamination was very evident, though much twisted, and the rock was more like Nos. 383G and 384G. The massive syenyte is seen again on this point just east and west of the line between sections 26 and 27.

In the N. W. ¼ N. W. ¼ N. W. ¼ sec. 26, the syenyte is found on the shore. Just north of it the graywacke-like rock is seen; this becomes somewhat more crystalline, as shown by Nos. 443G and 444G, and it seems to pass gradually into No. 445G, which is a distinct gray gneiss. However, this gneiss was seen to hold sharply defined lenticular pieces of rock similar to some facies of the greenstone. No. 446G shows the gneiss and part of one of the lenticular pieces in it. The junction of the gneiss and syenyte was not seen. The syenyte here presents a decidedly gneissic structure, but this grades into the more massive facies within two or three feet. The phenomena here seem to be about the same as those described under Nos. 404G to 409G; the gneiss (No. 445G) is apparently a changed condition of the graywacke-like rock, although in some places the two are separated by a sharp line. Fifteen feet north of this the graywacke-like rock again appears; it is nearly vertical, and, while bent in some places, there is a decided general strike of N. 60° E. At times the rock is similar to Nos. 383G and 384G, and again like No. 443G. This graywacke-like rock continues northward for about 200 feet and then the syenyte occurs. The two are separated by low ground with no exposures.

The syenyte continues northeastwardly along the northwest shore of this bay (N. ½ N. W ¼ sec. 26) for some distance, and in it is a band of the graywacke-like rock ten feet wide. This is sharply marked off from the syenyte on each side, and is distinctly laminated, striking northeast. In some places this band is similar to No. 443G, but the most of it is mica schist, as shown by No. 447G. On the north side of this bay hills of greenstone are seen in the N. W. ¼ N. W. ¼ sec. 26. The greenstone and syenyte were seen within fifty feet of each other, but the junction was not found. The syenyte becomes schistose and chloritic near the greenstone, as has been described farther to the west. Within 300 feet of the greenstone the syenyte holds irregular sharply outlined pieces of the greenstone, which are from one to ten feet in diameter. On the weathered surfaces these pieces very closely resemble the greenstone in the hills just to the north, but on freshly broken surfaces the rock is seen to be slightly darker than the greenstone in the hills. No. 448G is from one of these pieces in the syenyte. The greenstone in the hills near the syenyte has a schistose structure, as shown by No. 449G. This is twisted and somewhat irregular, but the general strike is N. 65° E., and the dip about vertical. The rock is lighter in color than the ordinary greenstone and contains some feldspar which weathers reddish. A short distance to the east the greenstone assumes the characteristic green color seen farther to the west, but the schistose structure does not altogether disappear. On the eastern side of the small point on the north shore of this bay the syenyte occurs in a low outcrop. It is here in contact with the graywacke-like rock, but seems to enclose masses of this rock. The syenyte here is mostly massive, but in a few places shows a gneissic structure

which runs northeastwardly. There are pieces (a foot or so in length) of the graywacke-like rock enclosed in the syenyte; most of these are facies of the rock approaching mica schist. These pieces are mostly irregularly lenticular in shape, and the lamination is parallel with their long axes, which usually lie in a northeasterly direction. Syenyte occurs on the east shore of this bay.

The shores of the little bay which lies partly in the extreme southern part of section 23 are lined with syenyte of the ordinary massive kind. About 100 yards north of the northwest corner of the bay is a hill of syenyte which presents the schistose and chloritic character seen several times in close proximity to the greenstone. At the extreme eastern end of the bay the syenyte is seen in contact with a dark dioryte (No. 450G), which is spotted by large blotches of hornblende. The contact line is sharp, as shown by No. 451G, and neither of the rocks appears changed at the contact. The syenyte is cut, on the eastern shores of the bay, by a coarse-grained pegmatyte (No. 452G). This consists of large flesh-colored feldspars and small quartz grains, and often shows a true pegmatitic structure.

From this bay to the rapids, in the E. ½ S. E. ¼ sec. 24, the north shore of the river has numerous outcrops of the ordinary massive syenyte. No mica schist or graywacke-like rock was seen along this shore, although special search was made for them.

On the south shore of the river, in the N. W. ¼ sec. 25, there is a westerly facing gabbro cliff. On the face of the cliff was a small area, a foot square, of a reddish syenyte bearing much biotite. The specimen collected (No. 460G) shows this rock and the gabbro. No other rock, except the gabbro, was found on the cliff. Just at the foot of the cliff was a large block of gray syenyte (No. 461G) and several small red syenyte fragments (No. 462G); these looked as if they had been broken off from the face of the cliff. This is possibly the line of junction between the syenyte and the gabbro, but nothing more than above stated could be seen. The gabbro was the ordinary coarse-grained facies.

The syenyte of section 24 varies a little from that described from section 27. It is represented by No. 463G, which is somewhat finer grained than the ordinary facies and is lighter in color, being more of a gray than a red syenyte, but on weathering it takes on a reddish color.

The river in the S. W. ¼ sec. 19, T. 63-9, has two rapid channels around a small island, not shown on the township plat. The portage is along the south shore of the southern channel. At the east end of this portage gray syenyte, similar to No. 463G, occurs. Just beyond the portage and on the south shore of the island, is a dark rock (No. 464G), which seems to be intermediate between the gabbro and the syenyte. It is a very compact rock of medium grain and uniform dark color, and on a freshly fractured surface shows in places yellowish color due to minute cracks; on weathered surfaces it has the appearance of the gabbro. This rock grades into the syenyte (No. 467G), through Nos. 465G and 466G. The syenyte was found at only one place, and that at the foot of a low cliff; the change from No. 464G to the syenyte, occupies two or three feet. This seems to be the junction of the gabbro and the syenyte, but no true gabbro was found on the island, and it is not certain that No. 464G does represent the contact facies of the gabbro. Near the eastern end of the island gray syenyte, shown by No. 469G, is again seen. The ordinary coarse-grained gabbro (No. 468G) occurs on the south shore of the river just opposite this island, and on this shore no syenyte was found. From this island the syenyte continues along the west side of the river to the western end of the little bay in the S. E. ¼ N. W. ¼ sec. 19, T. 63-9. The only exception to this is that on the south side of the point about the centre of sec. 19, T. 63-9, the gabbro, similar to No. 468G, is seen in a low outcrop. Thirty feet north of this gabbro is a gray rock (No. 470G), which seems to be intermediate between the gabbro and the syenyte. And 100 feet north of this the syenyte is again seen. There is no continuous exposure between this syenyte and the gabbro mentioned above. In places on a little island, which lies just off the end of this point, the syenyte has a gneissic structure which stands about vertical and strikes N. 40° E.

Small lakes (T. 63-10, north of the Kawishiwi river). Starting from the river, on the line between sections 28 and 29, is a portage which runs north to a narrow lake, which lies in sections 15, 16, 20 and 21. The portage crosses several greenstone ridges. These present an extremely massive appearance; this is especially noticeable towards the north end of the portage. No. 412G fairly represents this greenstone; it is a dark green aphanitic rock; it was taken from an outcrop on the portage about an eighth of a mile north of the section corner. Greenstone of the same massive kind, with no evidence of schistosity or lamination, extends along the shores of this lake in section 20. At the west end of the lake a dike of gray granite porphyry (No. 413G) cuts the greenstone. The general direction of the dike is east and west, but not enough of it was exposed to show the exact width, though this is probably not more than fifteen feet. In the rock are many quartz and feldspar phenocrysts, some of the latter being a half an inch in length. Macroscopically this rock closely resembles No. 417G. A small island, in the W. ½ S. W. ¼ N. W. ¼ sec. 21, also shows more of this granite porphyry. Greenstone extends along the north shore in section 21, but on the point, in the N. W. ¼ N. E. ¼ of the same section, there is a bluff of a fine-grained red-weathering siliceous rock (No. 414G), which is probably a facies of quartz porphyry. Just north of this bluff the greenstone occurs, but the junction of the two rocks was not seen. Greenstone appears to make the rest of the lake shore, but on the east side of the little bay (south shore of the lake), in the W. ½ N. E. ¼ sec. 21, a dike of quartz porphyry is seen cutting the greenstone. This dike is fifty feet wide, stands vertical and strikes a little north of west; this strike would carry it directly into the rock (No. 414G) mentioned above, which is probably a continuation of this dike. The contact between the greenstone and quartz porphyry is sharp and distinct, and the former does not seem to be especially altered near this line. The centre of the dike is much coarser grained than the edge. No. 415G shows the greenstone within two inches of the dike; No. 416G is the quartz porphyry two inches from the edge of the dike, and No. 417G is the

same from the centre of the dike. The quartz porphyry No. 417G is of a general pinkish color; it contains many quartz and feldspar phenocrysts, the latter being white and flesh-colored.

The shores of this lake seem to be made entirely of greenstone, cut in a few places by quartz porphyry dikes. The greenstone is very massive and in no place where examined shows any evidence of lamination or schistosity. It is well represented by No. 412G, from the portage south of the lake, and by No. 418G, from the north shore on the line between sections 16 and 21.

From this lake there is a trail running north on the line between sections 15 and 16 to a small lake lying in the N. W. ¼ of sec. 15 and the N. E. ¼ of sec. 16. No rock is *in situ* along this trail, but at the shore of the latter lake the greenstone is in place. The shores of the lake, as far as could be seen from the meander corner, were lined with rock which had all the appearance of greenstone. On this trail and a few yards south of the lake is a low hill, the north side of which shows many angular fragments of rock. This rock is made up of alternating bands of compact black slate and bands of almost pure magnetite. These bands vary from one-eighth of an inch to an inch in thickness. They are very regular, and on the whole the rock is very similar to some Keewatin ore described from Ottertrack lake.* The fragments of this rock were of all sizes up to those three feet in diameter, and while no pieces were exactly *in situ*, still there can be no doubt but that the rock is *in situ* just below these fragments. No. 419G represents this rock.

From the north shore of the Kawishiwi river, in the N. E. ¼ S. W. ¼ sec. 24, a portage runs northwesterly to the southeast corner of Triangle lake. This lake lies in secs. 13, 14, 23 and 24, T. 63-10. Just north of the river the portage crosses a low ridge of gneissic syenyte, and a short distance beyond is a ridge of the graywacke-like rock. This latter is shown by Nos. 453G, 454G and 455G. Just east of the portage this ridge is seen to better advantage; here the strike is N. 60° E., and the dip vertical. Fifty feet north of this ridge massive greenstone (No. 456G) is seen. The two rocks were traced within thirty feet of each other, but the junction was covered by soil. Beyond this more greenstone ridges are seen on the portage; usually the rock is massive in appearance, but it sometimes shows an indistinct schistose structure which stands vertical and strikes about northeast. About half way over the portage is a ridge of greenish, finely laminated rock, represented by No. 457G. The lamination is very distinctly seen on weathered surfaces, and in places the rock is decidedly slaty. The strike is N. 65° E., and the dip vertical. This rock seems to be a facies of the greenstone. Beyond this rock greenstone is seen in several places on the trail before reaching Triangle lake. Several outcrops on the east shore of this lake were examined, but the rock was all greenstone.

From the northeast corner of Triangle lake a portage of a few yards leads to Northwestern lake, which lies in secs. 11, 12, 13 and 14, T. 63-10, and secs. 7 and 18, T. 63-9. On the south side of a small island, in the N. E. ¼ N. W. ¼ sec. 13 (Northwestern lake), is a low outcrop of altered quartz porphyry (No. 458G). This rock has the groundmass almost entirely changed to a sericitic condition, but it still contains many porphyritic quartzes and large pinkish feldspars. Some of the feldspars are an inch long; they can be readily broken out of the groundmass, and they show complete crystal outlines. The sericitic groundmass gives a rough schistose structure to the rock; the strike of this is N. 60° E., and the dip about vertical. The south shore of this lake was examined in several places and the greenstone was the only rock seên; this extends to the extreme eastern end of the lake in the N. E. ¼ sec. 18, T. 63-9. On the north side of the lake, in the N. E. ¼ N. E. ¼ sec. 13, T. 63-10, the greenstone has a peculiarly mottled appearance. This is shown by No. 459G. It is due to numerous black blotches, apparently of hornblende.

(1). Greenstones and jaspilyte. At the northern side of the plate there is a belt of rock which is composed very largely of greenstones and greenstone schists which are closely associated, at least geographically, with jaspilyte and iron ore. Some of the general characters and relations of these greenstones have already been given in the field notes just presented. These rocks occur in typical development at Kawasachong falls and in that vicinity. Here they have been studied by Prof. N. H. Winchell, and his notes on them are given below.†

Kawasachong falls.‡ The rock here exposed was referred to in the report of 1880 (No. 356). It is an important and typical rock of the region, and seems to play a leading part, in towns further south and east, in producing some of the principal topographic features. It is represented by samples Nos. 997, 998 and 999. It is a green doleritic rock, more or less affected by decay; lies in heavy, irregular bedding that slopes northward at a greater angle than the descent of the river through the rapids from Garden lake to Fall lake. This bedding is variously blocked out by joints, and sometimes it shows a columnar structure. The beds are unconformable with some jaspilyte which appears on the right bank near the head of the rapids, and on the trail near the same

* *Seventeenth Annual Report*, pp. 112, 113.

† *Fifteenth Annual Report*, pp. 319-329.

‡ The Grand Marais Indians apply the name *Kawasachong* to Fall lake, meaning mist or foam lake, referring to the spray and mist produced by these falls, visible to the canoe-man who coasts along the shore past the mouth of this river. This name and this spelling were obtained of the well known Indian guide and trapper, Paul Morrison, by the writer in 1878, and, on account of some doubt of their correctness, they were again given by him to the writer in 1886.

place, apparently lying on the upturned vertical beds of the jaspilyte. This jaspilyte is more correctly styled a magnetic quartz schist. It stands in sheets nearly vertical, yet dipping north. It is dark-colored, but sometimes is reddened with hematite. Sample No. 1000.

This heavily bedded, rough, refractory doleritic rock can be of no other than eruptive origin. It is supposed to be inferior to the principal gabbro masses of the Mesabi range, as will appear by further descriptions, and some phase of it forms the contact rock on other, nearly vertical, strata in nearly all places where the junction line can be seen. It extends southward indefinitely, giving some characteristic outcrops on Garden lake and in the eastern portions of Kawishiwi valley.

The geological situation at Kawasachong falls is expressed, in general, by the following diagram, which shows a section north and south through the falls:

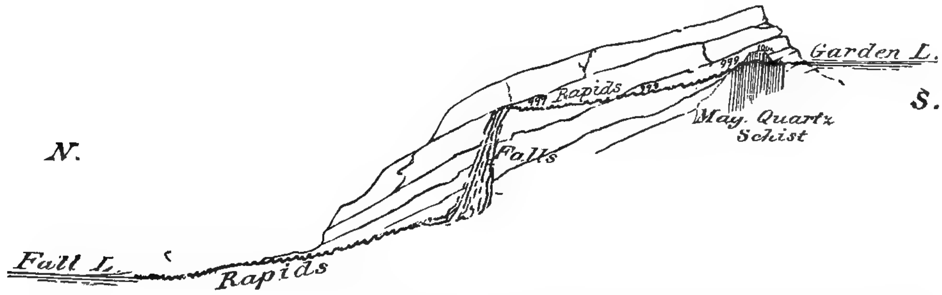

FIG. 64. PROFILE THROUGH KAWASACHONG FALLS, FROM FALL LAKE TO GARDEN LAKE.

The south shore of Fall lake. Westward from the mouth of the Kawishiwi river, the rock that forms the falls continues, forming rather high land, particularly in the point that projects into sec. 17, T. 63-11. It appears at the shore on the point in the northeast corner of sec. 19, T. 63-11, where the bluff rises about twenty feet.

Near the centre of sec. 19 T. 63-11, at the lake shore, is a confused "sericitic schist," near the water, coarsely fissile lenticularly, not soft, but with a jagged upper surface, represented by No. 1004. The prevailing structure in this dips southerly. Above this rock, in the same bluff, is a rock represented by No. 1005, which is a doleritic rock, probably the representative of the Kawasachong Falls rock. It has a coarse jointage, and an

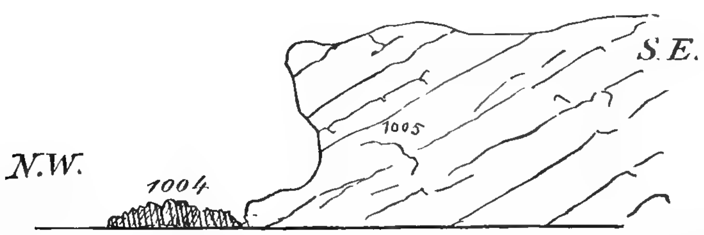

FIG. 65. BLUFF WEST OF KAWASACHONG FALLS, SOUTH SHORE OF FALL LAKE.

irregular coarse bedding that dips about northwest, at an angle of 30° from the horizon. This cannot be seen here to overlie, nor to pass into, the rock near the water (No. 1004), but it is possible that the rock near the water is only a rotted and disintegrating condition of that in the upper part of the bluff. There is a greater difference in the outward prevalent structure than in the mineral composition.

At the sharp point projecting southwestward, a little further southwest, but near the centre of the same section, is an interesting exposure which seems to shed light on the nature and origin of the rock forming the Kawasachong falls. A rock which resembles the schist No. 1004 occupies the lake shore nearly all about, at the water level. But at, or near, the extremity of the point, on the north side, the rock which forms the falls of the Kawishiwi, and which seems to be continuous to this place in the uplands, appears in the form of a dike rising through those schists, the contact on the south side of the dike being plainly visible. One is crumpled schistose, fine-grained, hardened, the schistose structure running north-northeast, at an angle of about 75° from the horizon; and the other is coarsely jointed, the main jointage system being, as stated before, at an angle of about 30° from the horizon. The colors of the two approach the same tint of doleritic green, and the hardening action of the dike is perceptible for some distance on the schist. Figure 66 shows the relative position of this dike, and the shape of the joint formed by it.

One of the interesting points about this exposure is the widening of the area of the eruptive rock toward the east, by means of overlie on the schists. This is inferred to have taken place at other places, notably on the jaspilyte near the head of the rapids from Garden lake, as shown by figure 64, but at no place has the actual contact and overlie been seen so boldly exhibited as at the place indicated on the map.

A cross section of the point, showing this overlie, would be about as represented by figure 67, the observer looking about northeast. The line of contact and of change of structure is not so abrupt as the figure indicates,

the eruptive rock being welded on the schists, the schists becoming diabasic, and making a rock similar to that which is seen on the eastern branches of the Kawishiwi where the same conjunction of geological features is exhibited. The entire transition, excepting the general hardening of the schists, is completed within the space of an inch, or even less. Indeed on close inspection it is apparent that a mere film, or a line only, evident on the face of the bluff by a thread-like groove, separates the two rocks in many places.

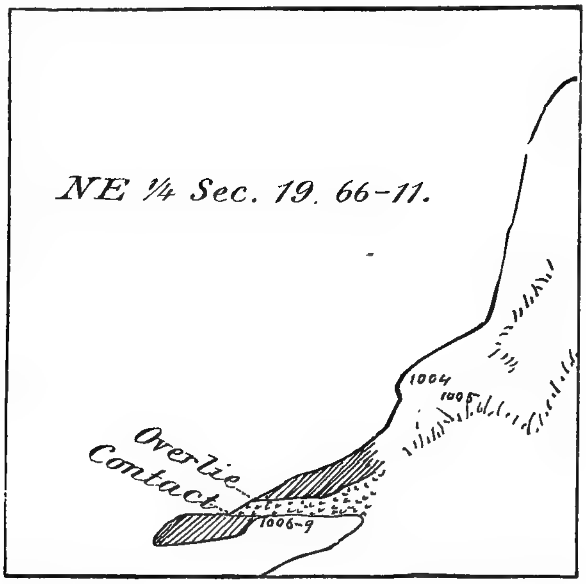

FIG. 66. SKETCH-MAP OF A POINT ON THE SOUTH SHORE OF FALL LAKE.

No. 1006 represents the schist near the dike.

No. 1007. Small specimen of granular quartz with pyrite disseminated, got in contact with No. 1006. There is very little of this. It is evidently due to the effect of the dike on the rock through which it comes.

No. 1008. Obtained two feet from the dike, on the south side.

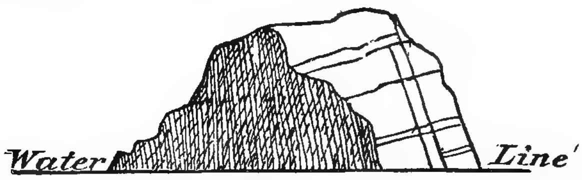

FIG. 67. OVERFLOWING DIKE ROCK LYING ON SCHIST.

No. 1009 is a sample of the dike rock.

No. 1010 represents the contact, containing some of each rock, at the place represented in figure 68. But this specimen does not fairly show the flowage structure in the diabase. It is difficult to get a specimen containing all the characters.

Parallel with the line of contact, in the diabase, the weather brings to light what might be styled properly a flowage structure, while the schistose structure is continued in the schists squarely up to the line of contact, the two systems of lining making an angle, at the contact line, of about 20°, as in figure 68 on page 411.

The flowage structure in the diabase extends indistinctly, sometimes about three inches from the line of contact. It is made visible on the weathered surface by the more rapid whitening of one of the constituent minerals which, for some reason, was disposed along the contact in somewhat greater abundance in thin parallel lines.

This is probably but one of the smaller outlets for the igneous rock seen at Kawasachong falls and further south and east. It forms a great stratum, lying unconformably on the schists here, apparently descending toward the valley of Fall lake.

A trail passes south from the bay in sec. 19, T. 63-11, to the head of the bay, extending from Garden lake into sec. 30, T. 63-11. In the S. E. ¼ of sec. 19 is a hill which is broad and heavily timbered, and at various places near the top are outcrops of jaspilyte, but whether they are transported masses from the main range further south, now embraced in the igneous matrix which forms the main rock of the hill, or are themselves a part of the rock *in situ*, could not be learned from any observations made. The jaspilyte is more nearly a black banded magnetited quartz schist. At one point some surface working has been done, but there is shown no dip or strike, simply a breccia of quartz schist cemented by quartz veins. The rock of the hill on which this occurs is

represented by No. 1011, which was seen at a number of places in small outcrops between the lake shore and the top of the hill. It is essentially the rock that forms the Kawasachong falls.

On the trail running south through sec. 19, T. 63–11, after passing an irregular elevation that seems to be made up of igneous rock, and then a low space, there intervenes another ridge made of a coarse greenish gray rock, resembling a modified graywacke of a rather fine grain (No. 1014). This is but little south of the section line between sections 19 and 30, and to the west of the trail. It rises about fifty feet above the trail. This rock seems to vary toward the rock that makes the falls of the Kawishiwi. But this variation is due probably to the action of that rock upon it when the two came into contact at the time of the eruption of the molten rock.

At the lake shore, in the N. E. ¼ sec. 30, T. 63–11, is rock No. 1015, which is identical in mineral character with the last. This is found where the trail from Fall lake reaches the bay in section 30, and shows its sedimentary origin more evidently than further north. It is fine-grained, brecciated, rising in a rough and coarsely jointed manner in hills about fifty or sixty feet above the lake, and extending in a series of short, overlapping ridges westward, rising a hundred or a hundred and fifty feet above Garden lake.

About through the centre of sec. 30, T. 63–11, runs a series of ridges, showing more or less of jasper hematite (No. 1016). Their direction is 10° south of west. This range is on the south side of the hills mentioned (No. 1015), and they show a crumpled and broken banding of iron and jasper, the latter being sometimes red, but never having, so far as seen, a persistent dip or strike. Several parties have located land for iron mining in this section.

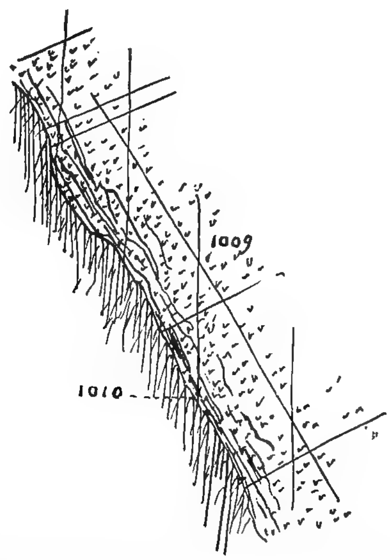

FIG. 68. SHOWING THE LINE OF CONTACT OF THE DIKE ROCK OF FIGURE 66 ON THE SCHISTS AND THE FLOWAGE STRUCTURE IN THE DIKE.

At one point, east of the centre of the section, the bands of jaspilyte have a direction N. 60° E. over quite a large area. It is associated with a greenish wackenitic rock which seems to be worthy of the name of porodyte in some places. This doubtful rock lies both on the north and on the south sides of the ore. It is not, however, apparently conglomeratic.

About Garden lake. The island in sec. 20, T. 63–11, near the outlet of Garden lake, consists of the same rock as that at Kawasachong falls, a green diabase, but has some of the schistose structure, due to disintegration, that is visible at the falls. But the greater part of it is entire, or massive. Similar rock extends along the shore of the lake southwest from this island, nearly to the bluff at the head of the bay in section 30, where it gives place to a changed graywacke (No. 1014), as already noted. In one place, on the north side of this long arm, about in N. W. ¼ sec. 29, T. 63–11, this is so much changed by, and mingled with, diabase that it does not differ much from the diabase. The most notable difference is in having a pinkish-red, weathered exterior, in some small areas, and in being porphyritic and quartzose in others. It has a streamed or flowage structure in narrow belts that surround lenticular, structureless areas from six inches to twelve inches in diameter.

On the point on the south side of the lake, in the S. W. ¼ of sec. 21, T. 63–11, is black or red jaspilyte, so far as visible mainly in loose pieces, but so abundant that the bed rock must be near. These are under water except at very low stage. The black, magnetited condition of this jaspilyte is less able to resist frost and weather, separating in curving and conchoidal sheets parallel with the bedding.

There will be some difficulty in separating by mapping, if not by obvious mineral characters, the changed graywacke seen about the west arm of this lake and elsewhere, from the diabase. I cannot do it in the field with satisfaction. It will require a more careful study of the specimens collected. Still this belt of rock so indefinite is not very wide. It pertains to the contact phenomena. There is a wide distinction apparent between the typical rocks, and sometimes these differences are brought into abrupt contrast by a sudden transition, but

it is usually not so. The transition is usually gradual, the more enduring, noticeable distinction being a lighter green color, and a siliceous aspect in the wackenitic rock, *i. e.* an acidic character, and a dark green or basic character in the diabasic.

About on the section line, between secs. 21 and 28, T. 63–11, on the south side of the lake, just south of the little point at which appear the foregoing detached fragments of jaspilyte, is an exposure of green diabase over which one may walk, on a glaciated surface, for a distance of fifty or sixty rods. This is at the level of the lake, and is partly flooded when the water is high. Here can be read a very instructive lesson in metamorphism. There is a transition, under the varying influence of the lake at higher or lower levels, and the slight difference in crystalline texture at different places, on the same rock surface, from nearly a massive doleryte to a green chlorite schist. The gradations in structure, color and mineral character are indistinguishable from foot to foot over the surface, but the extremes, exhibited at the opposite ends of the uncovered rock beach, are so great that one would hesitate, without such ocular demonstration, to admit that they are different conditions of the same rock. Perfect facility here is afforded for the inspection of every inch of this rock surface. This is the doleryte (or diabase) that has been referred to as lying unconformably on the jaspilyte, and as constituting the rock at the falls of Kawasachong. It here changes to a green chlorite schist, and recalls at once the green schist seen to have the same relation to the jaspilyte at Tower. It almost demonstrates the eruptive origin of that green schist.*

No. 1017. Green schist with disseminated striated crystals of white calcite that rapidly effervesce in acid, and some granular (?) quartz, such as seen in the green schist at Tower, in small lenticular patches. From the foregoing outcrop N. W. ¼ of sec. 28, T. 63–11.

No. 1018. Similar schist, from the same exposed surface, but showing no white crystals; same place.

No. 1019. Similar schist, less schistose; same place.

No. 1020. Similar rock, hardly schistose; same place.

No. 1021. Similar rock, but evidently changed from an igneous rock; same place.

No. 1022. Changed doleryte; same place.

No. 1023. From the midst of the very schistose parts (Nos. 1017–1018) showing a preservation of firmness and massive structure in some places; from the same place.

The strike of the schistosity is E. 23° 30′ N., and vertical. There is no banding of sedimentary structure in this rock.

On an island about three-fourths of a mile further east, in the bed of the river, the strike of the schist is E. 15° N. It here verges more evidently toward the Kawaschong falls rock.

At Quinn's, N. W. ¼ of sec. 27, T. 63–11, among the boulders of granite, etc., are some of jasper and hematite. The rock in outcrop is diabasic, apparently belonging to that last mentioned, though weathering rather light-colored, and in that respect resembling the modified graywacke.

At Julian Bausman's, S. W. ¼ sec. 23, T. 63–11, is a good showing of iron, though visible in several isolated outcrops, and at no place in large amounts. It is not worked yet, nor uncovered. It is probably in the range of that noted in the S. W. ¼ of sec. 21, T. 63-11, and appears like it. Mr. Bausman says it is traceable, by needle mainly, being magnetic and rather black-red, through the rest of this section and eastward. Rock No. 1024, obtained at Bausman's, S. W. ¼ of sec. 23, T. 63–11, is a somewhat schistose magnetic iron ore. This does not show the usual character of the ore here, so far as can be seen, but one of the forms it takes.

This sample gives:

Iron,	47.07
Titanium,	Trace
Chromium,	None

In sec. 21, T. 63–11, according to Mr. E. Byrne, a ridge of black jasper and magnetite, or two of them in one place, extends from near the east side of the section nearly due west, becoming involved with, or "covered by," at least replaced by, a quartzose poroditic rock, No. 1H and No. 283W. After an interval of about 150 feet of this rock, the same black rock recurs, and extends westwardly. It is next seen further south, where it constitutes a distinct ridge, and is traceable through two-thirds of section 21. This iron ore is represented by No. 1025. This iron range seems to continue, with more or less interruption, through secs. 23 and 13 in T. 63–11, and appears also in the next town east.

On the N. W. ¼ of sec. 28, T. 63–11, a diabasic green rock (No. 949) cuts a greenish, hard, finely schistose rock (No. 948), the contact being well exposed on the south side for a distance of a few feet. A schist somewhat resembling this, but more nodular, and more like an igneous breccia of schist and diabase, forms a small island in the S. E. ¼ of sec. 20, T. 63–11. It dips south, but stands nearly perpendicular.

This greenstone formation varies much in general aspect, being sometimes a massive dioryte or altered diabase, and again being a very soft fissile green schist. In some places, as just described above, near the line between secs. 21 and 28, T. 63–11 W., the schistose rock is seen to be directly derived from the massive rock, the former being a part of the latter, which has been subjected to dynamic action.

*Subsequent microscopical examination of this schist and even of the rock of the Kawasachong falls, showed that they are all probably fragmental, although often associated with diabase.—N. H. W.

In general these rocks are composed of green hornblende and feldspar, with frequently other minerals, such as chlorite, biotite, quartz, epidote and magnetite, but the green hornblende is the all-pervading constituent. In a few cases these greenstones seem to show fragmental grains, but in such cases it is difficult to determine without farther work whether such occurrences represent tufaceous deposits or clastic rocks derived from pre-existing greenstones. In very many cases the rock presents characters which cannot be referred with certainty to a definite origin; such rock is usually schistose. In many other cases the rock (compare Nos. 1009, 1011, 1015, 1018, 1020, 1023) evidently was originally an igneous rock of the nature of diabase.

From the field descriptions and from what has been seen of these greenstones in the vicinity of Fall and Garden lakes and elsewhere, it seems clear that, as a group, these rocks are distinct in origin from the jaspilytes with which they are so intimately associated.* The main mass of these greenstones are basic igneous rocks, and those in the area of the Gabbro Lake plate are regarded as, in general, of later date than, and intrusive into, the jaspilytes. It is quite likely that parts of these rocks also represent surface flows and fragmental volcanic material, while smaller parts were perhaps deposited in the form of water-assorted fragmental volcanic material, or as detrital material derived from pre-existing greenstones.

In the chapters devoted to the Snowbank Lake, Fraser Lake and Akeley Lake plates mention is made of some possibly pre-Keewatin greenstones, *i. e.*, those belonging to the Fundamental Complex. Rocks of this age have not been recognized in the area of the Gabbro Lake plate, although they may exist, but such rocks probably do exist to the north, in T. 64-10 W. The greenstones here described, and also the jaspilytes, are referred to the Lower Keewatin.

The jaspilytes, as already stated, occur in close association with the greenstones, and frequently are completely surrounded, at least at the surface, by these rocks. The location of some of the jaspilyte masses are as follows: In T. 63-11, especially in section 30; also in section 20 just east of the stream connecting Garden and Fall lakes, in S. W. ¼ sec. 23, and in section 21.

(2). Quartz porphyry. Rock of this nature exists in dikes which cut the greenstones in a number of places. These rocks are light gray to reddish in color, and are very distinct from the greenstones. Commonly, porphyritic quartz crystals are present, but sometimes they are lacking, while porphyritic feldspars are always present. One of the most noticeable of these dikes runs east and west near the top of the greenstone ridge which lies just to the north of the Kawishiwi river in secs. 28 and 29, T. 63-10. Others of these dikes have been described in the field notes already given.†

* Compare, also, the descriptions in the chapter on the Snowbank Lake plate.

† No. 300G, p. 401; No. 381G, p. 403; No. 403G, p. 404; No. 411G. p.; 405 No. 413G, p. 407; No. 417G, p. 408; No. 458G, p. 408.

(3). *Mica and quartz-magnetite schists.* Situated just to the south of the greenstone belt is a belt of schistose rocks which lie between the greenstone and the granite. The exact age of these schists is not known, but they are supposed to belong, also, to the Lower Keewatin. Their relation to the greenstone and jaspilyte is not certain.

At the outlet of White Iron lake, a locality known as "Silver City," and in the immediate vicinity, are some quartz-magnetite schists, which stand nearly vertical and strike towards the north-northeast. These rocks vary much in composition; they are finely banded and certain of the bands could be called magnetite schist, quartz schist, mica schist and hornblende schist. Some of them seem to be grünerite (or cummingtonite) schists (No. 950), and others contain garnet (No. 1113). Farther east, as around Farm and Friday lakes and along the Kawishiwi river in Ts. 63-11 and 63-10, the schists are typical mica schists. In places the schists are more like graywackes, which is thought to have been their original condition, their more crystalline character being due in large part to the granite just to the south. The field relations and the general appearance of these mica schists have been described in the field notes already given, and a description of a small area in Farm lake is here added.*

S. W. ¼ N. E. ¼ sec. 34, T. 63-11. Geology island. I first walked over most parts of this island, and found its geology very complicated. It does not even appear what is the fundamental formation. I find syenyte diabase dikes, mica schist, hornblende schist and siliceous schist under various aspects and alternations. In the following description I will begin at the south end, and, following the west shore, note what appears.

The numbers in figure 70 show the points referred to in the following description:

1. At the southeastern extremity of the island. Mica schist, striking N. 61° E., and with a southeasterly dip of about 75°. It is intersected by many veins of quartzose syenyte (figure 71).

2. The mica schist is traceable uninterruptedly to this, the most southern point of the island, at frequent intervals intersected by veins of compact syenyte. At 2*a* is a mass of syenyte not in form of a vein.

3. Mica schist more compact, weathering into columnar forms. About six rods from 2.

4. Here a mass of syenyte is included in the schist.

5. Very fine, compact, heavy-bedded, biotitic syenyte gneiss. This is reached by gradation from regular mica schist, both in the direction of the strike and across it. It is intersected by many masses of reddish granulyte. In the granulyte are also included vein-like forms of quartz, or rather flint. Here also are veins of beautiful syenyte, with large crystals of hornblende. An interesting case is shown in figure 69.

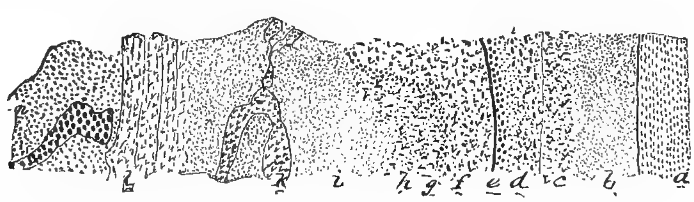

FIG. 69. DETAILED GEOLOGY OF A POINT ON GEOLOGY ISLAND, IN FARM LAKE.

a—Mica schist, very fine and compact. *b*—Fine, hard, almost vitreous diabasic matter, running with the bedding, but dike-like and not separated by any line from *c*. *c*—First comb of a syenyte vein in which the ample crystals of hornblende have their longer dimension transverse. *d*—Second comb of syenyte, in which the hornblende crystals have their longer dimension coincident with the walls of the vein. *e*—A comb of granulyte not isolated on either side, very vitreous. *f*—Third comb of syenyte, in which the hornblende fragments are variously disposed. *g*—Second comb of vitreous granulyte. *h*—Fourth comb of syenyte, in which the hornblende is disposed as in *c*. *i*—Nearly like *b*. *k*—A vein of common syenyte. *l*—A portion which has become gneissic, but very fine and flinty. *m*—A black substance resembling hornblende pulverized and compacted again. *Rock 132 W*—The black substance last mentioned. *n*—The portion indicated as red and smoky quartz at this point varies in character from foot to foot. It becomes, perhaps, predominantly a flinty granulyte, with lumps of smoky quartz. The whole mass passes to the water's edge as a regular dike five and one-half inches wide, with a strike N. 68° E. and a dip S. 61°.

7. For two feet beyond this dike the rock is a flinty, fine syenitic gneiss; and this is succeeded by a fine mica schist, in which small grains of quartz are abundantly visible, but, besides, is curiously full of rounded

*A. WINCHELL. *Fifteenth Annual Report*, pp. 82-88.

lumps of quartz and quartzyte about an eighth of an inch long, with transverse diameter less. It contains also quadrangular crystals of feldspar from one-fourth to one-half inch in length. This mass embraces plenty of granulyte intrusions. It extends a distance of thirty feet. It embraces a mass (dike-like) of granulyte which in parts contains an abundance of excessively fine scales of mica.

Rock No. 133 W. Porphyritic mica schist.

Other irregularly intruded masses are abundant, and some of them consist of very fine feldspar and quartz, with very few small scales of mica.

8. Mica schist, fine and well characterized, continuing sixteen feet, and becoming a fine hornblendic mica schist. Then with obscuration of separate grains of hornblendic (or augitic) material it passes into a diabase-like rock.

9. Diabase-like rock—or perhaps a mere graywacke—nineteen feet. It is intersected by many dikes and veins of fine granulyte and fine syenyte.

10. Mica schist, very fine. Mica seems to be muscovite. Rock variable like all the others—passing to a graywacke aspect and then distinctly a muscovitic schist. All profoundly intersected by dikes and veins of greenish granulyte. Continues twenty-five feet. Stops at a dike eight inches wide.

11. Mixed mass of hornblende schist and intrusions of granulyte and syenyte. Inextricable confusion. Also large inclusions of porphyritic syenyte.

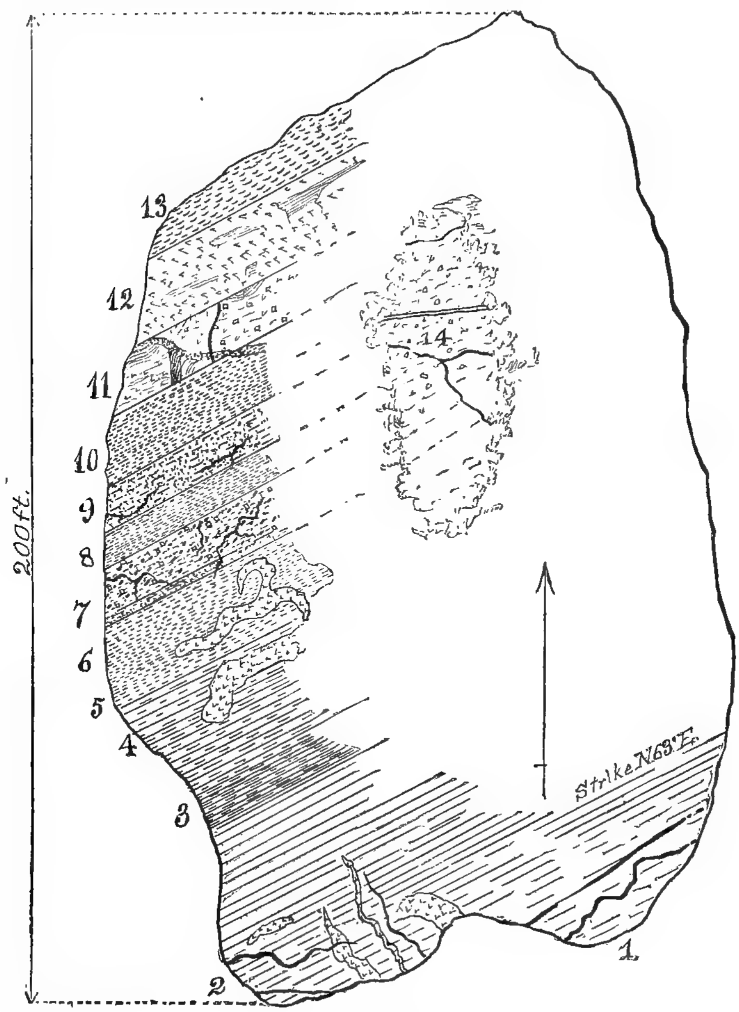

FIG. 70. GENERAL GEOLOGY OF GEOLOGY ISLAND, IN FARM LAKE.

12. Syenyte, typical, with coarse hornblende, including masses of hornblende schist, twelve feet.

13. Mica schist, intermingled as usual.

14. An exposure which is fundamentally hornblende schist—in places muscovitic -but contains imbedded pebbles of various kinds, giving it in places the appearance of a plum pudding. These pebbles are mostly rounded, and among them I recognize: (*a*) Semivitreous granular quartzyte; (*b*) Granular quartzyte; (*c*) Fine syenyte; (*d*) Syenyte with scattered large grains of quartz; (*e*) Smoky quartz.

The exposure is intersected by a two-inch dike of beautiful dioryte, consisting of hornblende and a pale greenish feldspar. Also by veins of quartz. The conglomeratic character is confined to a distance of about twelve feet.

I have given this little island quite a detailed and patient examination. Fundamentally it appears to be mica hornblende schist, but in a state of unstable equilibrium, sometimes turning to mica schist, and at others to hornblende schist.

But the whole mass was formed in immediate proximity to syenytes and granulytes, and these have been injected into it with infinite diversity of form, direction and volume. The schists and the other rocks are kneaded together, and in places the attrition of the parts produced true conglomeratic constituents. Afterward, when the formation became somewhat consolidated, it was rent by firm-walled fissures which were filled by the various dike materials—granulyte, fine syenyte and dioryte.

This little island, not even indicated by the land surveyors, possesses remarkable interest geologically, a wonderful concentration of rock varieties, geological incidents and forms, and well deserves the name of Geology island.

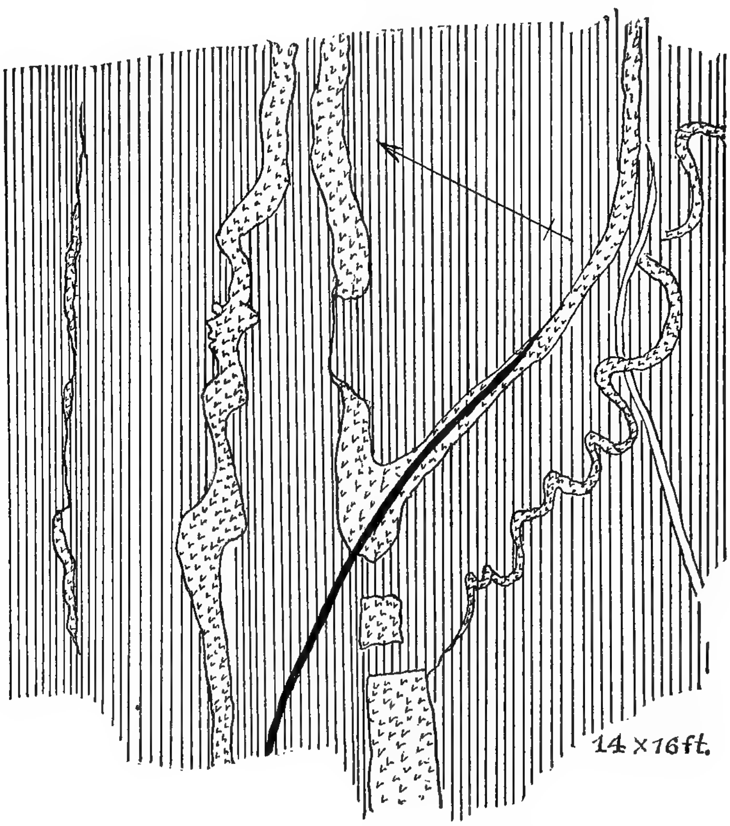

FIG 71. VEINS OF QUARTZ AND QUARTZOSE SYENYTE IN MICA SCHIST, GEOLOGY ISLAND, FARM LAKE.

(4). The granite. Occupying practically the triangular area between the two parts of the Kawishiwi river is a mass of granite which is the eastward extension of the same granite which makes the Giant's range in St. Louis county. This rock is a hornblende granite, but towards the east the quartz becomes less prominent or lacking and the rock is strictly a hornblende syenyte. The syenitic facies is especially common in the eastern half of this plate. The granite is of later date than, and intrusive into, the rocks which have already been described, but it has not been seen in contact with the jaspilytes, and its relation to the quartz porphyry dikes in the greenstone is not known. Contacts of the granite and greenstone are to be seen near the northwest shore of White Iron lake; of the granite and the quartz-magnetite

schists on the east shore of this lake south of "Silver City"; and of the granite and mica schists in many places; see, especially, figure 63 on page 402 of this chapter.

The granite has had a profound effect upon the rocks with which it has come in contact. The greenstones, especially when included as fragments in the granite, have been changed to coarse diorytes, and, as has already been stated, the crystalline condition of the mica schists is regarded as largely due to the granite. In T. 63-10 W. a graywacke like rock, which is part of the mica schist formation, has been completely recrystallized and now resembles a fine red granite, but this is distinct from the main mass of the granite and usually preserves evidences of its former lamination.

Associated with the granite, and cut by the granite, on the east shore of White Iron lake, are exposures of rather coarse dark rocks which are composed of feldspar and hornblende, and sometimes biotite. They are thus diorytes. They may have been originally coarse diorytes, or it is possible that they represent parts of the greenstone formation included in and entirely recrystallized by the granite. Other dioritic rocks are found associated with the granite in T. 63-10, and these, in part at least, seem to be more basic facies of the granite itself.

Quite commonly fine-grained granite (aplyte), composed almost entirely of feldspar and quartz, is seen cutting the main mass of the granite in branching dikes of various sizes. Frequently these aplytes are of a bright red color and are very noticeable.

The Animikie. One mass of the Animikie rocks is known from this plate. It is a part of the taconyte or iron-bearing member of the Animikie included in the gabbro, and is similar to the occurrences of such strata noted in the description of the Fraser Lake plate (chapter xxiii). The location of this mass of Animikie is just north of Musk Rat lake, in S. E. ¼ sec. 30, T. 62-10, and it is described as follows:*

Going south on the range line between T. 62-10 and T. 62-11, on the south side of the river in S. E. ¼ sec. 13, T. 62-11, search was made for the iron ore reported by Mr. Lorenzo Cleaves. Nothing was found for half a mile except syenyte in a ridge about seventy-five feet, by aneroid, above the river. Then there is a swamp and a creek, and gabbro hills are reached in S. W. ¼ sec. 19, T. 62-10. These hills are but a little over 100 feet above the Kawishiwi. The gabbro is seen in bare knobs and vertical bluffs twenty to forty feet high. Some masses of gabbro thirty feet in diameter have been pushed up on top of the smoothed knolls of solid rock and left there by the ice.

In the S. E. ¼ sec. 30, T. 62-10, are several shafts, some more than twenty feet deep, in magnetite ore. The magnetic attraction is very strong here and the needle dips 90° There being more than a mile and a half of gabbro north of this place and this iron ore itself being in hills of gabbro 100 feet high, it would naturally be supposed that this ore is gabbroitic magnetite and therefore titaniferous.

But the ore is olivinitic and generally quite fine-grained, and the rock which contains it is not a massive crystalline rock like gabbro, but stands in beds which are nearly vertical, though the dip is not constant. These strata are olivinitic, and, besides being finely granular, possess a banded structure and are evidently *transported beds of Animikie strata contained in the great gabbro overflow.* Whether they are between overflows of different dates or were surrounded and taken to their present position at the time of a single eruption, was not evident, but the latter is more probable. The gabbro itself being also largely composed of magnetite here renders it more difficult to distinguish between the two kinds of rock. Samples from the S. E. ¼ sec. 30, T. 62-10, showing banded structure supposed to be due to sedimentation are No. 407H. Specimens of the coarse gabbro magnetite are No. 410H. The Animikie is quite hornblendic here, as at the locality north of Birch lake,

*H. V. Winchell. *Seventeenth Annual Report*, pp. 96, 97.

sec. 24, T. 61-12. The gabbro, which forms massive knolls all around this place, is not so much decayed as the iron quartzyte, nor does it display any banding, nor any other signs of bedding, as do the enclosed strata of Animikie. The general strike of the latter is east and west.

An analysis of the magnetite supposed to belong to the enclosed beds of Animikie, and therefore to be non-titaniferous, was made by Mr. C. F. Sidener. No titanium being found in it, the effect of the gabbro does not seem to have been intense enough to invest the magnetite with harmful ingredients.

Silica (SiO_2),	11.39
Alumina (Al_2O_3),	Trace
Magnetic oxide of iron (Fe_3O_4),	85.55
Titanium (TiO_2),	None
Lime (CaO),	.22
Magnesia (MgO),	3.44
Phosphorus (P),	.02
Sulphur (S),	Trace
	100.62
Metallic iron (Fe),	61.95

The Keweenawan. More than half the area included in the Gabbro Lake plate is underlain by the great gabbro mass of northeastern Minnesota. This is referred to the Cabotian or lower division of the Keweenawan. Practically all the district (here described) south and east of the Birch river is covered by the gabbro. A feature of this rock, which is well developed in this district, is its separation into parallel layers. In some cases these layers are due simply to a splitting of the rock along certain parallel planes, as is frequently the case with igneous rocks. In other cases the layers or bands alternate with those of somewhat different composition or grain.

As is usual, the gabbro varies somewhat in composition, the chief variations in this district being from a rock which is largely or entirely composed of feldspar to one in which olivine is an essential component. In the latter the weathering of the olivine often gives a reddish tinge to the rock. On a preliminary field map Dr. A. H. Elftman has indicated a belt of olivine gabbro in the feldspar-rich gabbro. This belt is about three miles wide, and it extends northeast and southwest. Its northwestern limit is approximately a line drawn from the western end of Bald Eagle lake southwest to sec. 30, T. 61-10.

(1). Diabase dikes. A few fresh diabase dikes are seen cutting some of the older rocks, especially the granite. These dikes are thought to represent the latest rock in the region, although in the area of this plate they have not been seen cutting the gabbro. They are referred to Keweenawan age. Samples of these dikes are No. 346G from the west shore of Clearwater lake and No. 370G from the south shore of the Kawishiwi river just north of the centre of sec. 26, T. 63-10.

ECONOMIC RESOURCES.

By far the most important element of mineral wealth in this plate is the iron ore. The northern part of the plate contains the same formations as exist a few miles to the west, where the extensive hematite deposits of Ely occur. It is thus in the eastward extension of the Vermilion iron range. Several localities for jaspilyte

have already been mentioned, and others are also known, where explorations for iron ore may meet with success. The most promising locality at present seems to be on section 30, T. 63–10, which has been so long in litigation, and is well known as the famous "section 30." Here systematic exploitation of the ore is now (1897) being conducted. The prospects that paying iron mines may be developed in the Gabbro Lake plate are encouraging. Explorations for iron ore will be more likely to succeed in the district shown on the map as underlain by greenstone and jaspilyte.

GEOLOGICAL MAP.

The geological boundaries in T. 63–10 are regarded as practically correct, and it is not expected that future work will alter them materially, but in T. 63–11 the data at hand will not enable us to be as confident regarding the lines separating the different formations. No attempt has been made to separate the Lower Keewatin from the Upper Keewatin in the area of this plate, and it is doubtful if rocks of the latter age occur here. The contour lines are only approximately correct.

ROCK SAMPLES.

The following rock samples have been collected within the area of the Gabbro Lake plate:

N. H. Winchell's series: Nos. 356; 948–954; 979; 989–1000; 1004–1025A; 1110–1133; 1136; 1444–1447; 1709; 2111, 2112; 2215–2226.

A. Winchell's series: Nos. 93–111; 120–137; 139; 150, 151; 292, 293; 980–987.

H. V. Winchell's series: Nos. 407–415.

U. S. Grant's series: Nos. 101–114; 127–131; 139–146; 299–457; 460–463.

A. H. Elftman's series: Nos. 8–10B; 27–29; 107–117; 120–128; 131A–140; 146–150; 153B, 154; 158.

CHAPTER XXII.

THE GEOLOGY OF THE SNOWBANK LAKE PLATE.*

By U. S. GRANT.

Situation and area. The Snowbank lake is situated in the centre of the northern side of Lake county. On the west is the Gabbro Lake plate (plate 78), and on the east the Fraser Lake plate (plate 80). The Snowbank Lake plate, so called from the lake of that name in the centre of the plate, comprises Ts. 63–8, 63–9, 64–8, 64–9, 65–8 and 65–9, all west of the fourth principal meridian. The last two townships are very incomplete, bordering on Canadian territory, and Ts. 64–8 and 64–9 also border on Canadian territory in the vicinity of Prairie portage. The area of the plate, inclusive of water surface, is about 147 square miles.

SURFACE FEATURES.

Topography. The area of this plate consists of two topographical divisions, a southern and a northern. The southern division comprises that part of the district which is underlain by gabbro. It is here rough and hilly, and does not exhibit the undiversified surface which is seen in some of the gabbro country in the plates to the east of this plate, but at the same time it is less rugged than the district to the north, which is underlain by Archean rocks. In the latter area the hills are more pronounced, and are frequently precipitous. Moose and Newfound lakes have on either side hills of this character, the lake basins lying in soft schistose rocks, and the adjacent hills being of more enduring rock. Around Snowbank lake, and the shores of Bassimenan (Basswood) lake, places where granite is the underlying rock, the surface is not so rough.

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*The area of this plate has been examined at various times by different parties of the survey and some of the field notes have been published. The individuals who did the work, the dates of the work, and the places of publication are as follows: N. H. WINCHELL, field work of 1878, *Ninth Annual Report*, pp. 87–98; field work of 1886, *Fifteenth Annual Report*, pp. 345-352, 358–360; field work of 1887, *Sixteenth Annual Report*, p. 110; field work of 1892, published in part, *Twenty-first Annual Report*, pp. 156, 157; field work of 1897 and 1898, *Twenty-fourth Annual Report*. A. WINCHELL, field work of 1886, *Fifteenth Annual Report*, pp. 99–101, 119–142, 144, 145; field work of 1887, *Sixteenth Annual Report*, p. 196. H. V. WINCHELL, field work of 1886, *Fifteenth Annual Report*, p. 441; field work of 1888, *Seventeenth Annual Report*, pp. 115–128. U. S. GRANT, field work of 1888, *Seventeenth Annual Report*, pp. 163, 164; field work of 1891, *Twentieth Annual Report*, pp. 55, 56, 59–69. A. H. ELFTMAN, field work of 1893, published in part in *Twenty-second Annual Report*, pp. 141–180.

The writer's field work within the area of the Snowbank Lake plate has been confined principally to the vicinity of Snowbank lake and the relations of the granite there exposed to the surrounding rocks. He has also accompanied the state geologist on trips to Moose, Snowbank and Disappointment lakes and across the county from the Kawishiwi river to Moose lake.

Discussions and many details concerning the Archean rocks of the area of the Snowbank Lake plate have been given in the chapter (XI) on Lake county, and they are not repeated here,

GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.

SNOWBANK LAKE PLATE

COMPILED BY U.S. GRANT

Explanation

Cabotian

Animikie

Archean

Contour Lines

Trails

The highest point in this plate is near the line between secs. 34 and 35, T. 64–8 W., and is somewhat over 1,800 feet above sea level. The lowest water surface is Bassimenan (Basswood) lake, which has an altitude of 1,300 feet, thus making a difference of over 500 feet between the extremes of altitude in this plate.

Drainage. The Snowbank Lake plate lies in the drainage basin of Hudson bay. All the waters of the plate pass into Basswood lake, but the waters of the Kawishiwi river flow westward and then northward through Fall lake, before they reach Basswood (Bassimenan) lake. The lakes of the northern half of the plate drain directly into Basswood lake.

The drift. The general direction of last ice movement in the area of this plate, as recorded by the glacial striæ, was towards the south-southwest. No terminal moraine has been certainly located in this area, but Mr. Warren Upham has provisionally mapped the Vermilion or Twelfth moraine as passing through the southern part of this plate.*

Drift deposits, as in much of the adjoining country, are comparatively thin, and in places apparently entirely lacking, as in the vicinity of Wilder lake, where the following notes were taken.† A similar absence of drift is mentioned in the description of the Fraser Lake plate (chapter xxiii).

There is here no visible drift, or nearly none, except such as is referable to this rock. There are fine exhibitions of the process of making "*boulders by disintegration*," some bluffs being in process of decay but strangely retaining, undecayed, rounded boulder-like masses from two to six feet in diameter, the surrounding rock being so rotted that it can be picked to pieces by the fingers. There is no show of drift action, nor ice action, the rock everywhere being superficially crumbling off in flakes and in small bits, so that in some of the bays the beaches consist of gabbro sand. There is not a total absence of transported drift, but only very rarely a boulder of granite. These also show the disintegrating action of age. The gabbro bluffs do not look clean and smooth-cut, but are falling down *in situ*, the joints being worn out so as to produce little channels in which water runs down to the lake. Old weathered surfaces are pitted with holes of all sizes, up to a hen's egg. On the tops of the hills is a thin, often gravelly, soil produced by the decay of the gabbro rock. The sand of the beaches in small bays where it gathers is made up of labradorite crystals, more or less rotted. The whole of Wilder lake has these driftless characters. They seem to show that at the last Glacial epoch this region was not subjected to moving ice. This kind of surface extends from the west side of the lake in sec. 33, T. 63–8, eastward at least as far as the east end of Wilder lake, beyond which this trip did not extend. Throughout this area, although the rocks are bare much of the way along the shores, not a glacial scratch nor a glaciated surface could be seen, although on our return special notice was given to this feature. At the west end of the lake in sec. 33, T. 63–8, was seen one moutonéd surface, but it had no scratches. Gradually in passing still further west the rocks assumed a more preserved condition, and occasionally a rounded surface appears, and at the entrance of the main river, southern part of sec. 30, T. 63–8, is a striated rock-surface, the lines running S. 8° E. Further still west, such surfaces are more and more common, and finally every surface, facing toward the north, is found to be striated, and all the rock is hard and fresh. This interesting series of change cannot be ascribed to any differences in the nature of the rock, because it is the uniform gabbro formation all the way, but must be referred to difference of glacial action. I think I saw also more frequent signs of transported drift about at the point where striated surfaces began to appear, though the drift in this part of the state everywhere is scant.

The more eastward direction of the marks noted above in section 30 is also significant. There was a little local disturbance of my needle at the point where the striation was noted, but an allowance was made for this by comparison with the direction of the needle at points near at which no disturbance was noticed. The normal direction of ice-flow in this part of the state, as noted further west, is S. 12° to 25° W. Hence the east margin of the ice-flow, which, according to Chamberlin, would have an outward movement from the axis toward the edge of the glacier, must have been that which produced these divergent scratches, leaving the country further east still uncovered.

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* *Twenty-second Annual Report*, pl. 1.

† N. H. Winchell. *Fifteenth Annual Report*, pp. 350, 351.

GEOLOGICAL STRUCTURE.

The Archean. Considerably more than half the district here described is underlain by rocks of Archean age, and about these centre many problems of geological and economic interest. Unfortunately most of the field work on this area was done before several important points concerning the divisibility of the Archean were fully appreciated. For this reason and also because of the lack of careful mapping, we are not able to always separate the different parts of the Archean. It can be stated, however, that the two divisions of the Keewatin, the Upper and the Lower, are present, and are separated by an unconformity and a conglomerate at the base of the former. It is also very probable that there are rocks older than the Lower Keewatin (*i. e.* rocks of the Basement Complex, as that term is used by the U. S. Geol. Survey), separated from it by an unconformity. There are granites of at least two dates, and there are also intrusive greenstones and quartz porphyries. In mapping the district it has not been possible, with the data at hand, to make a separation of the parts of the Archean strictly on an age basis, but the following divisions, mainly lithological, are shown on the geological map (plate 79): (1) Mica schists; (2) Greenstones, sometimes with jaspilyte; (3) Keewatin in general, including conglomerates, sericitic schists, argillytes, graywackes, greenstones, mica schist and a little jaspilyte; (4) Quartz porphyry and associated quartzless porphyry; (5) Granite.

(1). Mica schists. The only belt shown on the map is a narrow one just south of the Basswood granite. Not much is known of these rocks in this area, but they occur in characteristic development just to the west along the southern part of Basswood lake. Here they are well marked mica schists, with some hornblende schists, and they are intruded by the Basswood granite. In this category of mica schists are not included those parts of the mica schist around Snowbank and Disappointment lakes, which are clearly metamorphosed conditions of Keewatin clastics.

(2). Greenstone aad jaspilyte. In the northwestern part of T. 63-9 is a considerable area of greenstone which is continuous with the greenstone mapped and described in the chapter (xxi) devoted to the plate to the west of this (Gabbro Lake plate). This greenstone is seen in characteristic development at Northwestern lake, and to the east along the south line of sec. 7 and of sec. 8, T. 63-9. The high hill, near the southeast corner of section 8, is composed of this rock. These greenstones are sometimes schistose, but are frequently quite massive, and retain many of their original characters which show that they were in large part originally basic igneous rocks like diabases, diorytes or gabbros.

Associated with these greenstones are masses of jaspilyte, with which may also be deposits of iron ore. From the field notes of others, and from what he has seen himself, the writer feels justified in stating that the greenstones associated with the

jaspilytes are, in large part, igneous rocks of later date than the jaspilytes. Masses of jaspilyte, intimately connected with greenstone, are known from several localities, among which are the following: hills in the south half of sec. 32, T. 64–9; east line of sec. 5, T. 63–9, at the south shore of the small lake at the northeast corner of this section; north line of sec. 4, T. 63–9, between the two lakes near the northwest corner of this section. At the last locality are many irregular masses of jaspilyte in the greenstone, and the latter is cut by dikes of a fine-grained, reddish rock. The jaspilyte in the area of the Snowbank Lake plate, except, perhaps, that on the portage between Wood and Moose lakes (sec. 21, T. 64–9), is the same as that occurring elsewhere on the Vermilion iron range, and is in a belt directly continuous with the belt of jaspilyte at Ely.

Associated with these greenstones, in places, are areas of what has been called greenstone conglomerate. These contain fragments, more or less rounded, of greenstone in a green, usually schistose, matrix. From the descriptions it is often impossible to tell whether these beds represent tuff deposits of greenstone, or whether they are true conglomerates formed directly from the greenstones. A good example of one of the latter class is seen on the west line of sec. 9, T. 63–9, about one-fourth mile north of the southwest corner of this section.

To the northwest of Moose lake, lying southeast of the belt of mica schists and extending westward beyond the limits of the Snowbank Lake plate, is another area of greenstones. These, in the main, are rather fine grained, hard and siliceous, and frequently schistose. It is to this area of greenstones, and to the mica schists here mentioned, that reference was had when it was stated that pre-Keewatin or Basement Complex rocks very probably existed in the area of the Snowbank Lake plate.

(3). *Keewatin in general.* Here are included practically all of the Archean rocks except the greenstones and jaspilytes, part of the mica schists and the acid igneous rocks. In lithology, the Keewatin here embraces conglomerates, sericitic schists, argillytes, graywackes, mica schists, chloritic schists, greenstones and some greenstone schists. Whether all these rocks belong to the Upper Keewatin is uncertain, but some of them certainly do, as, for instance, some of the conglomerates, and it is probable that the main mass of clastics comprised in the belt which lies between Snowbank lake and Sucker lake also belong to the Upper Keewatin, but on this point no positive statement can be made.

The conglomerate belts cannot be outlined in detail, but one or more belts exist between Snowbank and Newfound lakes. Another occurrence is east of Disappointment lake, where the following field notes were taken:*

In the N. W. ¼ sec. 34, and S. W. ¼ sec. 27, T. 64–8, there is a most wonderful exhibition of conglomerate and diabase. Going east from the point in the N. E. ¼ sec. 33, the conglomeratic mica schist becomes coarser and more full of boulders. These consist of various kinds of light-colored crystalline and dark hornblendic

*H. V. WINCHELL. *Seventeenth Annual Report*, pp. 117, 118.

rocks; and are, many of them, a foot long. The mica schist gradually becomes harder and less siliceous until it is diabasic. East of the lake there are high ridges rising 75 to 150 feet above the water. These become more and more diabasic until they culminate in a high ridge of nearly massive diabase about a quarter of a mile from the lake. There is a coarse schistosity seen in this ridge in places. The strike of the rocks as shown by the schistosity, the direction of the longer axes of the boulders, and the foliation of the mica schist are all *about northwest.* These ridges offer one of the finest exposures of conglomerate and agglomerate seen in this entire region. The rock in places is just as full of boulders as it can be. These become smaller and more compressed toward the east, and disappear altogether in the vicinity of the diabase ridge. Some of the diabasic schist is porphyritic. Samples of the conglomerate are No. 497H. Diabasic schist is No. 498H. Diabase is No. 499H. Gneissic schist from the edge of the lake showing foliation, which was northwest, is No. 500H. Biotite schist from a well-defined dike about a foot wide, which cuts the diabasic agglomerate, running about east and west, is No. 501H.

It is quite remarkable that there is here a gradual transition from mica schist to diabase. There is no place where there is an abrupt change. The mica schist is conglomeratic and the diabase is agglomeratic. They are both schistose and have the same trend and seem to be vertical, as far as bedding is indicated by foliation and schistosity.

This transition from greenstone (diabase) to the conglomerate might be explained by the deposition of the conglomerate immediately above and almost contemporaneous with a greenstone agglomerate. Or, it might be explained by regarding the conglomerate and agglomerate as one, the lower part (agglomerate) being fragmental material derived directly from the underlying greenstone. The latter explanation seems the most likely, as it accords well with the fact that in several other places in northeastern Minnesota, the lowest part of the Upper Keewatin is composed so completely of debris derived from the immediately underlying rock that it is difficult to separate the two unconformable formations. At the locality just described the conglomerate also contains jasper pebbles, and we here most probably have the conglomerate at the base of the Upper Keewatin resting unconformably on the older greenstone.

Further notes concerning the Keewatin rocks are given below.*

Observations on the rock outcrops on the shores of Snowbank lake are found in the fifteenth, seventeenth and twentieth annual reports of the survey. The writer's attention was directed to the hitherto unexplored region, extending from the north shore of the lake to Moose, Newfound and Ensign lakes. Between Moose and Snowbank lakes five cross sections were made. On the south shore of the former lake the rocks are sericitic and argillitic schists. The range of hills extending parallel with the lake shore is composed of vertical beds of schists, argillyte and conglomerate. South of these hills, at points from one-fourth to three-fourths of a mile distant from the lake shore and then extending southward through a swamp and valley, are extensive outcrops of quartzless porphyry. This rock extends nearly to Snowbank lake, on the west shore of which is also a ridge of schists and conglomerates.

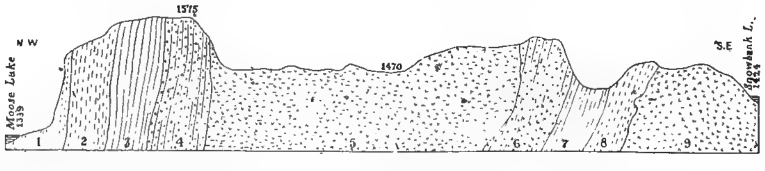

FIG. 72. CROSS-SECTION FROM MOOSE LAKE TO SNOWBANK LAKE, NORTHWEST TO SOUTHEAST.
Distance, two miles; altitudes expressed in feet above the sea-level.

The above section (figure 72) from the N. E. ¼ N. W. ¼ sec. 35, T. 64–9, on Snowbank lake northwest to the S. W. ¼ S. W. ¼ sec. 22, on Moose lake, fairly represents the rocks north of Snowbank lake. The direction is nearly northwest and southeast, directly across the strike of the vertical formations. Beginning at Moose lake the numbers, corresponding to those on the diagram, denote the different kinds of rocks occurring along this section.

* A. H. ELFTMAN. *Twenty-second Annual Report*, pp. 151-155.

1. Sericitic schist. At the lake shore this schist is dark in color, fine grained and has a greasy appearance. One hundred and fifty paces from the shore, at the base of a perpendicular cliff 100 feet high, is a light-colored sericitic schist (No. 165E) with small angular and round feldspars.

2. At the top of the cliff this rock grades into a schist (No. 164E), in which the feldspar nodules have developed to well-defined knots, one-fourth of an inch in diameter. The schists stand nearly vertical, dipping at different places slightly to the north or south. The strike is about northeast and southwest, although in some places along Moose lake it varies from east and west to nearly north and south. Two hundred paces from the top of the cliff the rock has changed to a dark argillitic, sericitic schist (No. 166E), in which the knotted structure has been developed to a greater extent. From the same outcrop specimen No. 167E shows feldspars two inches long. The weathered surface here looks somewhat similar to that of the finely concretionary greenstone of Ely.

3. Two hundred and fifty paces farther, and on the south side of a small swamp, is an extensive outcrop of argillyte (No. 277E). This rock breaks up into small chips and tablets an inch thick.

4. Two hundred paces from the last outcrop, in a dense balsam ticket, is a knob of conglomerate fifty feet in diameter. In the conglomerate are numerous rounded and angular pebbles of jasper, varying in size from very fine grains to those three inches in diameter. Many of these pebbles show beautiful banding. Besides this jasper are gneiss, granite and slate pebbles not exceeding four inches in diameter. The matrix of the conglomerate is fine-grained and green in appearance (No. 276E). In another outcrop of this conglomerate fifty paces northeast of here granite boulders a foot in diameter are common. The conglomerate forms the highest part of the ridge south of Moose lake.

5. In the next one hundred paces there is a descent of seventy-five feet into a swamp about a mile wide. Near the northern edge of the swamp is an outcrop of quartzless porphyry, which cuts the conglomerate and forms mica schist as a contact rock. In crossing the swamp there are occasional outcrops of porphyry.

6. In the N. W. ¼ S. W. ¼ sec. 26, T. 64–9, about two hundred paces west of Snowbank lake, the porphyry cuts a bed of conglomerate. This differs from No. 4 in that no jasper pebbles were found.

7. In the conglomerate are beds of epidote schist, and the whole grades into argillyte. No distinct boundary between this bed and the preceding one can be marked out.

8. About four hundred paces southeast of No. 6 and on the broad point in section 26 the argillyte grades into a hornblende mica schist which is considerably contorted and cut by a hornblende granite.

9. The granite continues to the shore of Snowbank lake in the N. W. ¼ sec. 35, T. 64–9.

Of this series of rocks the porphyry is the most important. Quartz porphyry dikes are of common occurrence in the Keewatin rocks of Minnesota, but in no place does it occur in such a large mass as it does west of Snowbank lake. Here it extends in a northeast and southwest direction from the centre of sec. 23, T. 64–9, through sections 27, 33 and 34, then westward to the west range line of T. 64–9, a length of five and one-half miles. It varies in width from three-fourths to one and one-half miles. The rock is exceedingly hard, but owing to the basaltic structure it readily breaks into angular blocks. The area in which this porphyry occurs is covered with these blocks. The readiness with which the porphyry breaks into angular blocks probably explains why it is found in a valley between ridges of mainly sedimentary rocks. Although these latter rocks are more easily abraded by the ice and at present decompose more rapidly, the porphyry, being easily broken off in large blocks, would be removed in much larger amounts, leaving a depression between the clastics. When freshly broken the porphyry has a purple to grayish color. On a weathered surface the rock is white and occasionally is stained yellow or red by ferric oxide. Porphyritic crystals of feldspar are numerous; those of quartz are rare and in the larger number of specimens are entirely absent. Under the microscope feldspar phenocrysts of all sizes, up to one-fourth of an inch in length, are embedded in a microcrystalline groundmass of quartz and feldspar. The feldspars are orthoclase and oligoclase and show a more or less altered condition. In No. 60E the feldspar has been replaced by quartz. Quartz phenocrysts occur only in small quantities and sometimes are pseudomorphs after the feldspar. Chlorite and epidote occur in small flakes throughout the rock. Biotite and apatite are rarely present. Specimen No. 49aE represents the quartzose phase of the porphyry. In thin section, besides the usual constituents, there are numerous quartz phenocrysts. These, with but one or two exceptions, occur as round grains with corroded edges, and have a wavy extinction. The feldspars are exceptionally well developed. Epidote is present in small plates and chlorite is scattered throughout the section.

Whenever the relations of the porphyry and the other rocks of this region could be determined it was found that the porphyry cuts the Keewatin rocks, sending dikes far across the strike of this formation. A great deal of the disturbance of the Keewatin rocks in this locality is due to the intrusion of the porphyry, and not, as it is generally supposed, to the granite of Snowbank lake, which is the youngest formation in the region. Dikes of granite (No. 56E) cut the green schist (No. 58E) and the porphyry (No. 55E) in the S. E. ¼ N. W. ¼ sec. 26, T. 64–9. This is the only place known where the relations between the granite and the porphyry could be determined with certainty. The general strike of Keewatin sedimentaries is parallel to the periphery of the porphyry mass. On the west shore of Snowbank lake this strike is somewhat modified by the granite intrusion.

In going from the bay in Snowbank lake in the N. W. ¼ S. E. ¼ sec. 24, T. 64–9, N. 20° W., to Newfound lake, the following outcrops of rocks were seen in the order given:

1. Mica schist and conglomerate in inseparable beds, the former becoming less schistose and micaceous as the distance from the granite area increases. 2. Argillyte. 3. Mica schist. 4. Coarse diabase. 5. Agglomeratic greenstone. 6. Conglomerate. 7. Argillyte. 8. Diabase similar to No. 4. 9. Conglomerate and argillyte. 10. Sericitic schist at three-fourths of a mile from Snowbank lake. This schist continues to Newfound lake.

The strike of the rocks mentioned above is nearly east and west, and toward the east this remains the same. One-half a mile west of the line of the cross section the strike of the rock is somewhat changed to a southwest and northeast direction. Farther west, near the north end of Moose lake, the strike, as previously mentioned, is nearly north and south.

In the region north of the central part of Snowbank lake, no outcrops of the porphyry, which is so abundant west of here, were found. On the west shore of Boot lake, in the S. W. ¼ N. W. ¼ sec. 21, T. 64-8, are several large dikes of this rock cutting the graywacke and schist in this vicinity.

In the S. W. ¼ N. E. ¼ sec. 21, T. 64-8, on the east side of the long point, in the midst of a bed of conglomerate, is a boss of granite partially uncovered. Dikes run out from this mass in all directions, cutting the conglomerate and distorting the strata in a very complicated manner. In the conglomerate are boulders up to four feet in diameter of gneiss, slate, diabase and granite. This last can scarcely be distinguished from the granite which cuts the conglomerate of the region. In several instances a granite dike traced several hundred feet, was found to cut some of the large boulders in the conglomerate. The contact between the dike and the granite boulders could not be determined easily. Parts of the boulders adhered to each side of the dike.

The conglomerate just mentioned (S. W. ¼ N. E. ¼ sec. 21, T. 64-8) is regarded as part of the base of the Upper Keewatin.

Conglomerates occur elsewhere in several places, as along the portage from Moose to Flask lake, along the east side of sec. 32, T. 64-9, and on the large peninsula on the northwest side of Disappointment lake. Details concerning some of these localities and others also may be found in the chapter on Lake county, and these details need not be repeated here. Perhaps one of the most interesting localities for a conglomerate is on the portage between Moose and Wood lakes, near the line between secs. 20 and 21, T. 64-9 W. Here is a conglomerate which contains interbedded strata of jaspilyte. It has already been described, page 279.

In a number of places the Keewatin sediments have been converted into mica schists, and this is especially true around Snowbank lake where mica schists are well exposed, as along the northwestern shore of the lake in secs. 24 and 26, T. 64-9. Mica schists are also found between Snowbank and Disappointment lakes and about Round lake. These schists are found in direct contact with and near to the granite masses, and they are referred in the main to contact metamorphism, induced by the granite, although dynamic metamorphism may also have aided in their development. Dikes from the granite frequently penetrate the mica schists. Some details of the geology about Snowbank lake, where the granite and mica schists occur, are given below.*

On the west shore in the N. ½ N. E. ¼ sec. 11, T. 63-9, a fine-grained syenyte (No. 482G) is seen; this is quite similar in appearance to Nos. 480G and 481G. Farther north syenyte is again seen on the shore; here it is coarser grained and not at all like No. 482G. This coarser-grained syenyte extends along the west shore into the northwest corner of the bay in the S. ½ S. E. ¼ sec. 2, T. 63-9. Here it is represented by Nos. 483 and 484; the former is a dark-red syenyte of medium grain, and the latter is of lighter color, contains less hornblende, and is the facies of the rock that is most common at this locality. Just off the point, which is in the N. W. ¼ S. E. ¼ sec. 2, T. 63-9, is a small island made of a coarser facies of the same syenyte (No. 485G). This is cut by veins, of all sizes up to three feet across, of a dull reddish, rather coarse-grained syenyte (No. 486G) made up almost entirely of feldspar; the other constituent is in small amount and seems to be epidote. The point crossed by the line between secs. 35 and 36, T. 64-9, is composed of dark dioryte of medium grain (No. 487G); this appears in the form of a dike, 100 feet or more in width. It runs about north and south. The syenyte was seen just east of this point and also along the shore west of it; here the syenyte is quite coarse-grained and contains much biotite (No. 488G). The point on the south shore, in the S. E. ¼ N. W. ¼ sec. 35, T. 64-9, shows syenyte of a rather fine grain (No. 489G).

* *Twentieth Annual Report*, pp. 60-67.

The bay which runs south along the line between secs. 34 and 35, T. 64–9, shows no outcrops along its shores. And on going west a short distance, near the township line, no rock was seen *in situ*. On the west shore, in the N. E. ¼ N. E. ¼ sec. 34, T. 64–9, a short distance north of the portage which runs to Flask lake, is a large bluff of fine-grained diabase. Farther north on the west shore of the narrow bay in the S. E. ¼ S. E. ¼ sec. 27, T. 64–9, the fine-grained, greenish diabase, here represented by No. 489aG, is cut by an irregular dike of reddish porphyry (No. 490G). This dike is from two to five feet wide and was traced for at least thirty feet. Another small mass of this same rock was seen near by, but it was exposed only in one place. This porphyry (No. 490G) has a reddish to purplish aphanitic groundmass, in which are porphyritic crystals of red feldspar and small areas of chlorite. Under the microscope the groundmass is seen to be microgranitic in structure, and apparently composed of quartz and feldspar. The feldspar phenocrysts are more or less altered, and the majority of them show polysynthetic twinning. Irregular areas of chlorite occur in the groundmass, but nothing is left to show what was the mineral that originally occupied these areas. A few small apatite prisms are present, and scattered through the whole rock are minute green flakes of chlorite. The rock is probably a syenyte porphyry.

No rock, except that above described, is seen on the shores of this narrow bay north of the south line of sec. 27, T. 64–9. But where this line crosses the east shore of the bay there is a low ridge which shows angular fragments of fine-grained greenish diabase, similar to No. 489aG. No rock is seen in place along the southwest shore of the promontory, on which are the corners of secs. 26, 27, 34 and 35, T. 64–9, but many angular fragments of the fine-grained diabase occur at the water's edge. On the sharp point, at the southern end of this promontory, angular fragments of the diabase and of porphyry, similar to No. 490G, are seen. Along the shore just east of this point are angular fragments of granite, and a little further north this granite occurs *in situ*. Several outcrops of the same are seen along the shore before coming to the line between secs. 26 and 35, T. 64–9. At this place No. 491G was collected; this well represents the granite from the east shore of this promontory. It is a granite of medium grain, reddish color and compact texture; the feldspar varies from reddish to white, and the hornblende is in small grains and does not make up more than one-fifth of the whole rock. Quartz is present in small amount. Under the microscope this rock (No. 491G) is seen to be a distinct hornblende granite. Quartz is present in larger quantity than is noticed in the hand specimen. The feldspar is more or less cloudy and many of the grains show a microcline structure and have a wavy extinction, as have also some of the quartz grains. The hornblende is quite fresh and of the ordinary green variety. A few scales of brown biotite are present, and also some green chlorite, which appears as an alteration product from the biotite. Bright brownish sphene is seen in considerable amount. Ilmenite, or magnetite, and apatite prisms are also present. This is the first true granite seen on this lake, but there is no reason to suppose that it is distinct from the syenyte found elsewhere on the lake; in fact, everything seems to indicate that it is but an acid facies of the syenyte. About 150 feet south of the above mentioned section line is a low outcrop of mica schist, much twisted and bent. This schist is represented by No. 492G, which is a fine-grained compact mica schist, and by No. 493G, which is coarser and more properly gneiss. A few feet north of this the same schist is seen again; here it is cut by many granite dikes, which vary from six inches to three feet in width. This granite is part of the same as that mentioned above (No. 491G). The dikes in general run along between the cleavage planes of the schist, but some were seen cutting across these planes. The schist here is sometimes much changed near the contact with the granite, as is shown by Nos. 494G and 495G, which are distinctly gneisses; the latter is decidedly reddish in color. There is no gradation from the schist or the gneissic parts of it into the granite; the contact between the two rocks is sharp and distinct, as is seen in No. 496G. This specimen shows the two rocks, granite and schist, in contact; it was taken from the edge of a dike one foot in width. The schist at this place is so twisted that no general strike can be made out. In places the granite includes pieces of the schist. A few yards north of this section line and back about a 100 feet from the shore is quite a large exposure of the schists. These are bent some, but there is a decidedly general trend to the strike; it is N. 35° E., and the dip is almost vertical. Just beyond (north) this exposure of schist, and in the strike of part of it, is another outcrop of the granite similar to No. 491G. On one of these outcrops there is a small amount, one by three feet in area and one foot thick, of purple porphyry; the contact with the granite was sharp and a distinct line, and there was nothing to show whether this rock was part of a dike or an inclusion in the granite. This porphyry is represented by No. 497G; it has a fresh unaltered appearance, and seems exactly similar to that already described under No. 490G, except that the latter is not very fresh. A short distance north of the section line (between sections 26 and 35) and about an eighth of a mile from the shore is a small island composed entirely of granite (No. 498G). This island is directly in the strike of the last mentioned outcrop of schist. The granite of the island (No. 498G) is of rather fine grain, and holds a considerable amount of quartz, but is the same granite as that described above (No. 491G). On the northeastern end of this island the granite is jointed in a very noticeable manner; the joints split the rock into parallel beds that stand vertical and strike N. 70° E.

On the south shore of the little bay, in the S. E. ¼ S. W. ¼ sec. 26, T. 64–9, the schist is seen in many places, and the granite is seen in contact with it at a few points. The schist here is well represented by the specimens collected near the south line of this section; and where the schist is in contact with the granite it takes on the same characters as seen in Nos. 494G and 495G. In one place a small tongue of the granite was seen running across the strike of the schists, as shown in figure 73. Along the shore of this bay the schist is twisted so much that no general direction of strike is noticeable.

On the south side of this bay, near its western end and down at the water's edge, the schist is cut by a small dike. This dike is four feet wide, but was not exposed for over seven feet. The walls are parallel, stand

vertical and strike N. 50° E. The line between the dike and the schist is very sharp. The dike rock is a purple porphyritic rock similar to that already described under Nos. 490G and 497G; it differs from these, however, in having distinct glistening biotite scales scattered through the groundmass. The rock may be provisionally called a syenyte porphyry. No. 500G is this rock from the centre of the dike, and No. 501G is the same from one edge of the dike. The schist at this place has a dip of 60° towards the east, and a strike almost due north and south. The schist from near the dike is represented by No. 499G; this is a rather fine-grained gray biotitic gneiss. In section this gneiss (No. 499G) is seen to be a holocrystalline aggregate of interlocking grains of quartz, feldspar, biotite and hornblende. Many of the grains are elongated somewhat in one direction—this is especially true of the biotite—and there seems to be a tendency for grains of the same size and of the same minerals to be collected somewhat in irregular parallel lines. This causes a decidedly schistose structure to pervade the rock. None of the mineral grains show any evidence of a clastic origin. The quartz is clear and limpid and is in larger grains than the other minerals; it makes up about half of the rock. The feldspar, while cloudy in small areas, is usually clear; most of it is orthoclase, but some good sized plagioclases are present. The biotite is brown and fresh. It, more than any of the other minerals, is chiefly confined to certain irregular lines. The biotite is in small scales, most all of which are arranged with their long axes in the direction of the schistosity of the rock. Hornblende of the ordinary green variety is present in a few irregular areas. It appears very fresh. All the minerals of the rock present a decidedly fresh and unaltered appearance.

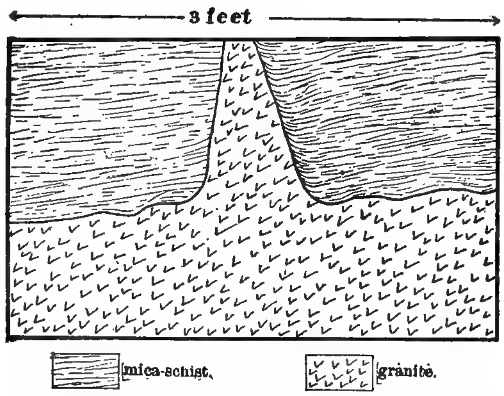

FIG. 73. CONTACT OF GRANITE AND MICA SCHIST.
S. E. ¼ S. W. ¼ sec. 26, T. 64-9, west shore of Snowbank lake.

The granite occurs at the west end of the little bay, in the S. E. ¼ S. W. ¼ sec. 26, T. 64-9, and also along the shore for a short distance north of this place. The point in the N. E. ¼ S. W. ¼ of the same section consists of a high ridge of green schists. These schists are hard and of a general green color. They seem to consist of mica, chlorite and siliceous matter very closely intermingled. The rock has a fine lamination, due to rapid alterations in the arrangement of the constituents, thus producing laminæ of different hardness and composition; this lamination is very clearly shown on weathered surfaces; it is parallel to the schistose structure of the rock. In places the schist is conglomeratic, containing pebbles of all sizes up to a foot in length, elongated in the direction of the strike. The strike is N. 20° E. and the dip is 75° to 80° towards the east. At the east edge of this ridge the schists are in contact with the granite. The contact line is sharp and runs parallel with the strike of the schists, but the granite sends off many small dikes into the schists across the strike. No. 502G represents these green schists. No. 502aG is part of one of the pebbles; it is a gray gneiss. No. 503G is the granite from one of the dikes four inches wide; this is a fine-grained, reddish hornblende granite.

The green schists extend from the point part way along the southeastern shore of the bay, in the N. W. ¼ S. W. ¼ sec. 26, T. 64-9, but on this side of the bay, near its end, is a dark, compact, aphanitic rock holding white feldspar phenocrysts. This is probably a porphyryte (No. 504G). It is massive at the shore, but on going back a few rods from the shore it becomes schistose, as is shown by No. 505G. This porphyryte was traced eastward until it came within fifty feet of the green schists, but soil covered the contact. The porphyryte and the green schist at this place each had their distinct characters. The schistose structure of the porphyryte is parallel with that of the green schist. In one place the porphyryte is cut by a dike of a fine-grained syenyte (No. 506G). This dike is four feet wide, stands vertical and runs east and west.

On the west side of this bay the green schists appear again and seem to get more massive on going northward, but the shore here was not carefully examined. In the S. W. ¼ N. E. ¼ sec. 26 massive greenstone, into which the green schist seems to grade, is cut by a dike of syenyte porphyry, similar to No. 500G. On the shore just north and east of this the greenstone and syenyte are seen together. The greenstone here is quite massive in appearance and the contact with the syenyte was seen in only one place. Here it was a decidedly sharp line and two small pieces of the greenstone were seen in the syenyte. At this place the syenyte also cuts a gray dioryte blotched with hornblende (No. 507G). The relation of this dioryte to the greenstone could not be determined. The syenyte is itself cut by a fine-grained greenstone (No. 508G), in a dike which varies from eight inches to two feet in width. This was traced for thirty feet. It may be that this is not a true dike, but a part of the

greenstone surrounded by syenyte, as it is decidedly similar to the greenstone and cannot be distinguished from it in hand specimen. The syenyte is here represented by No. 509G, which is a reddish rock of rather medium grain. The greenstone is shown by No. 510G.

Just north of this, mica schist is seen cut in every direction by dikes of the syenyte, which vary in width from two inches to thirty feet. The mica schist is shown by No. 511G. Farther north there is a large mass of the schist exposed; here it varies from a mica schist like No. 511G, to a green schist (No. 512G), which is very similar to the green schists described above. The strike here is N. 20° E., and the dip is about vertical. These schists extend along the shore up to and beyond the line between secs. 23 and 26, T. 64-9. Sometimes they are cut by dikes of hornblende granite, represented by No. 513G. Near this section line the schists become very hard and compact. No. 514G, from this place, is a very siliceous, fine-grained graywacke. Here the strike is N. 25° E., and the dip is about vertical. On a ragged bluff just north of this section line the schists are much crumpled and twisted, and they become hard and very siliceous. No. 515G fairly represents the schists at this place. The schists continue along the lake shore in secs. 23 and 24, T. 64 9. In places they are massive in appearance, but usually a lamination can be seen on their weathered surfaces; this, however, is much twisted in every direction, but there is a general northeasterly strike and a vertical dip. The schists in these two sections are well represented by Nos. 515G, 516G and 517G.

Where the line between ranges 8 and 9 crosses the north shore, granite occurs. It is represented by No. 518G, which is very similar to the granite and syenyte found elsewhere on the lake. The granite here cuts the schists in dikes running in every direction. Some of these dikes are apparently a hundred feet wide, while others are not more than a foot. The contact between the two rocks is a very sharp line, as is shown by specimen No. 519G, which was broken from the edge of a dike eight feet wide. The schists at this place are represented by No. 520G, taken within two feet of the granite; it is a fine, hard, siliceous mica schist. Here there is seen a small amount of a rather fine-grained dark augite granite (No. 521G); this is distinct from the granite and is cut by it. The relation of this rock to the schists could not be determined. Just east of the range line the schists are seen in large amount. Here the strike is N. 70° E., and the dip southward from 70° to 80°. The schists, sometimes cut by the granite, extend along the shore to the bay in the S. W. ¼ N. E. ¼ sec. 19, T. 64-8. On the west side of this bay the schists are graywacke schists. The strike is almost east and west and the dip varies from 65° to 80° towards the south. These schists are also seen at the north end and on the east side of this bay.

There is a small island in the N. E. ¼ S. W. ¼ sec. 19, T. 64-8, on the eastern end of which is a large exposure of gray to reddish augite granite of medium grain (No. 522G). Mr. Wood went over most of this island and found it to be made of the same rock.

Syenyte from the shore, in the N. W. ¼ S. W. ¼ sec. 29, T. 64-8, is of medium grain and light gray color. Small areas of the feldspar have a peculiar yellow stain (No. 523).

Several outcrops on the east shore of the large island, which lies in secs. 30 and 31, T. 64-8, and secs. 25 and 36, T. 64-9, were examined. They are all composed of rather coarse augite granite which holds large quantities of biotite (No. 524G). Coarse granite, similar to this, occurs on the east shore on the line between sec. 36, T. 64-8, and sec. 1, T. 63-9.

At the southwest end of the island that is crossed by the line between secs. 30 and 31, T. 64-8, there is an outcrop of fine-grained biotite gneiss (No. 525G).

Aside from the metamorphism suffered by the Keewatin clastics near the granite, they have also been altered and recrystallized by the gabbro. On the south side of Disappointment lake, and at Ima lake, the effect of the gabbro on the underlying Keewatin has been very marked. In fact, the latter lake, except for the southern side, which touches the gabbro, lies in a mass of these altered rocks. The Keewatin in such position has been partly or wholly recrystallized into a fine-grained, usually yellowish and granular rock, which varies in mineral composition as the original rock varied. To these rocks the name "muscovadyte" has been applied, but they are not to be confounded with some fine-grained gabbros and norytes which lie near the northern edge of the gabbro and to which the same name has been applied.*

(4) Quartz porphyry. In this district, especially west and southwest of Snowbank lake, in T. 63-9, are considerable areas of porphyritic rocks. These vary considerably, but in general are light-colored, gray to reddish, fine-grained rocks with porphyritic crystals of feldspar and also frequently of quartz. Some of the charac-

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* See remarks upon these rocks in the chapter on the Fraser Lake and Akeley Lake plates, and in that on Lake county, p. 302.

ters of this porphyry have already been given (see pages 425–428 of this chapter). As a whole, the porphyry seems not to have been subjected to great dynamic forces, and is still massive, breaking down in sharply angular blocks. The age of the porphyry is not known, in fact there may be porphyry of more than one date, but it is thought to be in general later than the Lower Keewatin greenstones, and earlier than the Upper Keewatin conglomerates, for it is found cutting the former and included as pebbles in the latter. The porphyry is probably of the same date as the porphyry dikes mentioned in the chapter devoted to the Gabbro Lake plate. Details concerning the occurrence of the porphyry in this Snowbank lake area can be found in the chapter on Lake county.

(5). Granite. The granite may be described under three areas, that of the Kawishiwi river, that of Snowbank and Disappointment lakes, and that of Basswood lake.

The granite on the Kawishiwi river is a small mass in sec. 19, T. 63–9. This is an eastward continuation of the Giant's Range granite. The gabbro soon passes over this area of granite onto the Keewatin rocks, thus completely shutting off the surface exposure of the granite, which rock is perhaps continuous, beneath the gabbro, with the granite at Snowbank lake.

At Snowbank and Disappointment lakes, especially at the former, much granite is seen. This lake lies in an area of this rock, which appears on the islands and at many places on the shores. There is evidence that there are here two masses of granite of different date, but the separation cannot be made with certainty, although it seems that one granite, a red or hornblende granite, is later than and cuts the other, a gray or augite granite.* That part of the granite at Snowbank lake is intrusive into the Keewatin clastics is evident, and on the shores of this lake in secs. 24 and 26, T. 64–9, this relation of the granite and the Keewatin mica schists can be seen in many places.† On the northwest shores of Disappointment lake is a conglomerate, which holds red granite pebbles very similar to dikes of granite, cutting this conglomerate. This necessitates the presence of a granite in this vicinity earlier than the conglomerate, as well as one later than the conglomerate. Whether this earlier granite is exposed near by is not known. Dikes of granite cutting a conglomerate with granite pebbles at Snowbank lake have already been mentioned.‡

At the northwest corner of the Snowbank Lake plate is a small part of the Basswood granite. This rock is of later date than the mica schists just to the south of it,§ and is also probably later than the ancient greenstones just south of these mica schists.

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*A. H. Elftman. *Twenty-second Annual Report*, p. 157.
†See pp. 425–428.
‡P. 426.
§P. 422.

(6). *Structure of the Archean.* The Archean rocks, as already stated, are divisible into two, and quite likely into three, unconformable series. Sufficient detailed work has not been carried on to allow us to discuss fully the structure of these different parts of the Archean, but it is quite evident (1) That after the deposition of the Lower Keewatin, these rocks were more or less complexly folded, and (2) That after the Upper Keewatin, the whole Archean area was again subjected to mountain making forces, which folded and crushed the rocks, at times metamorphosing them, and at times inducing a schistose structure or a slaty cleavage. The result was a complicated and closely compressed mass of strata whose complexity has been further increased by intrusions of igneous rock. The strike of the rocks varies considerably, but in general is towards the northeast or east-northeast. The folds into which the rocks, especially those of the Upper Keewatin, have been thrown are numerous, and, as now visible, consist usually of closely compressed synclines, the anticlines having been removed by erosion, thus leaving the older rocks exposed between the synclines of the later rocks. The basin of Moose lake lies in a syncline, most probably of Upper Keewatin rocks, whose axis runs northeasterly. The lake itself is in a mass of comparatively soft sericitic schists, while on either side rise the harder conglomerates and associated rocks flanked by still higher ridges of Lower Keewatin (or older) greenstones.

*The Animikie.** South of Disappointment lake, in sec. 3, T. 63-8, is a mass of Animikie strata lying at the north edge of the gabbro. The strata here dip south at a high angle and in lithological characters they are similar to the other banded ferruginous quartzytes or olivinitic iron ores, described in the chapters on the Gabbro Lake, Fraser Lake and Akeley Lake plates. Other Animikie areas are not known in this plate, but there is some evidence that a small mass of these rocks exists near the southern part of the west side of sec. 11, T. 63-9.

The Keweenawan. The gabbro, belonging to the Cabotian division of the Keweenawan, underlies a large part of the southern half of the Snowbank Lake plate. It has the same general characteristics and lithology as elsewhere, and it need not be described here. The gabbro lies on the Giant's Range granite at the western edge of the plate, but it soon covers this and passes over onto the Keewatin greenstones and mica schists; it lies on granite again, south of Snowbank and Round lakes, and then passes onto Keewatin rocks, on which, excepting the small mass of Animikie already mentioned, it rests throughout the remainder of its northern limit in this plate. The gabbro has had a profound effect upon the

*Since the writing of the chapters on the areal geology and the making of the geological maps, the state geologist has reached the conclusion that the mass of ferruginous rock, here described as of Animikie age, really belongs to the Keewatin. The same is true regarding all of the olivinitic iron ores formerly included in the Animikie, *i. e.* those at Akeley lake and westward, and at Gabimichigama lake, in Cook county, at several places in Lake county, and at Birch lake in St. Louis county. As the map and descriptions were completed before this conclusion was reached, they have not been changed. A discussion of this question may be found in the chapter devoted to structural geology in vol. v of this report, and details of this locality at Disappointment lake may be found in the chapter on Lake county, pp. 302-304.

older rocks with which it has come in contact, and this fact has already been noted.*

In the gabbro are some deposits of titaniferous iron ore, of which the following may be mentioned. About sixty yards northwest of the east quarter post of sec. 15, T. 63–9, is a mass of this ore which is exposed for a distance of 250 feet; it is ten feet thick, or more, and extends under a hill for an indefinite distance. In the N. W. ¼ S. E. ¼ of the same section is more of this ore. In the N. ½ N. W. ¼ sec. 29, T. 63–9, on the south shore of a bay of Crab lake, is a mass of lean, titaniferous magnetite which covers about ten acres.

Associated with the gabbro are small amounts of fine-grained gabbro, which is described more fully in the chapter on the Akeley Lake plate (chapter xxiv).

(1). Diabase dikes. Later than all the foregoing rocks, except, perhaps, the gabbro, are a few small diabase dikes, which are comparatively fresh, are uniformly very fine-grained on the sides, and have not been subjected to pressure or shearing. They are referred to the Keweenawan. One of these dikes cuts the granite in Snowbank lake, in sec. 1, T. 63–9; another, eighteen feet wide, and striking N. 57° E., cuts the argillytes at the east end of Ensign lake, in N. W. ¼ S. E. ¼ sec. 11, T. 64–8; another, ten feet wide, and striking N. 30° W., cuts the mica schists just north of the portage from Snowbank to Disappointment lakes in S. W. ¼ sec. 32, T. 64–8.

ECONOMIC RESOURCES.

Mention has already been made of the iron ore in the Animikie, and in the gabbro. The latter is titaniferous magnetite, and consequently at present cannot be used with advantage. In the N. W. ¼ T. 63–9, and immediately adjacent in T. 64–9, are a number of exposures of jaspilyte, some of which have been mentioned in the seventeenth annual report. While it is not possible to state whether or not there are any valuable deposits of iron ore in the district just mentioned, it is certain that the geological conditions are the same as in the greenstone and jaspilyte belt at Ely, which is directly continuous with the greenstone and jaspilyte belt in the Snowbank Lake plate. It is equally certain that the part of this plate mentioned above offers a good field for exploration for iron ore.

GEOLOGICAL MAP.

The contour lines are to be regarded as only approximately correct, indicating the general location of the high ground. In the northern part of T. 64–9, data for contours are lacking. The northern boundary of the gabbro, except possibly between Illusion lake and the southern side of T. 64–8, is thought to be located with approximate accuracy. The boundary lines of the different parts of the Archean are not

*P. 429.

regarded as located with accuracy. Future work may alter these considerably, and at the same time it will enable one to map the Archean more strictly on an age basis.

ROCK SAMPLES.

The following rock samples have been collected within the area of the Snowbank Lake plate:

N. H. Winchell's series: Nos. 329–331; 980–988; 1035–1039; 1715–1741; 2169–2214; 2227–2274.

A. Winchell's series: Nos. 187–251; 295–297; 525.

H. V. Winchell's series: Nos. 476–542.

U. S. Grant's series: Nos. 132–138; 464–539; 1068, 1069.

A. H. Elftman's series: Nos. 30–34; 39; 43–84; 90–92; 97–103; 129, 130; 162–169; 267–281; 285–287; 572–635; 637.

CHAPTER XXIII.

THE GEOLOGY OF THE FRASER LAKE PLATE.*

(PLATE 80.)

BY U. S. GRANT.

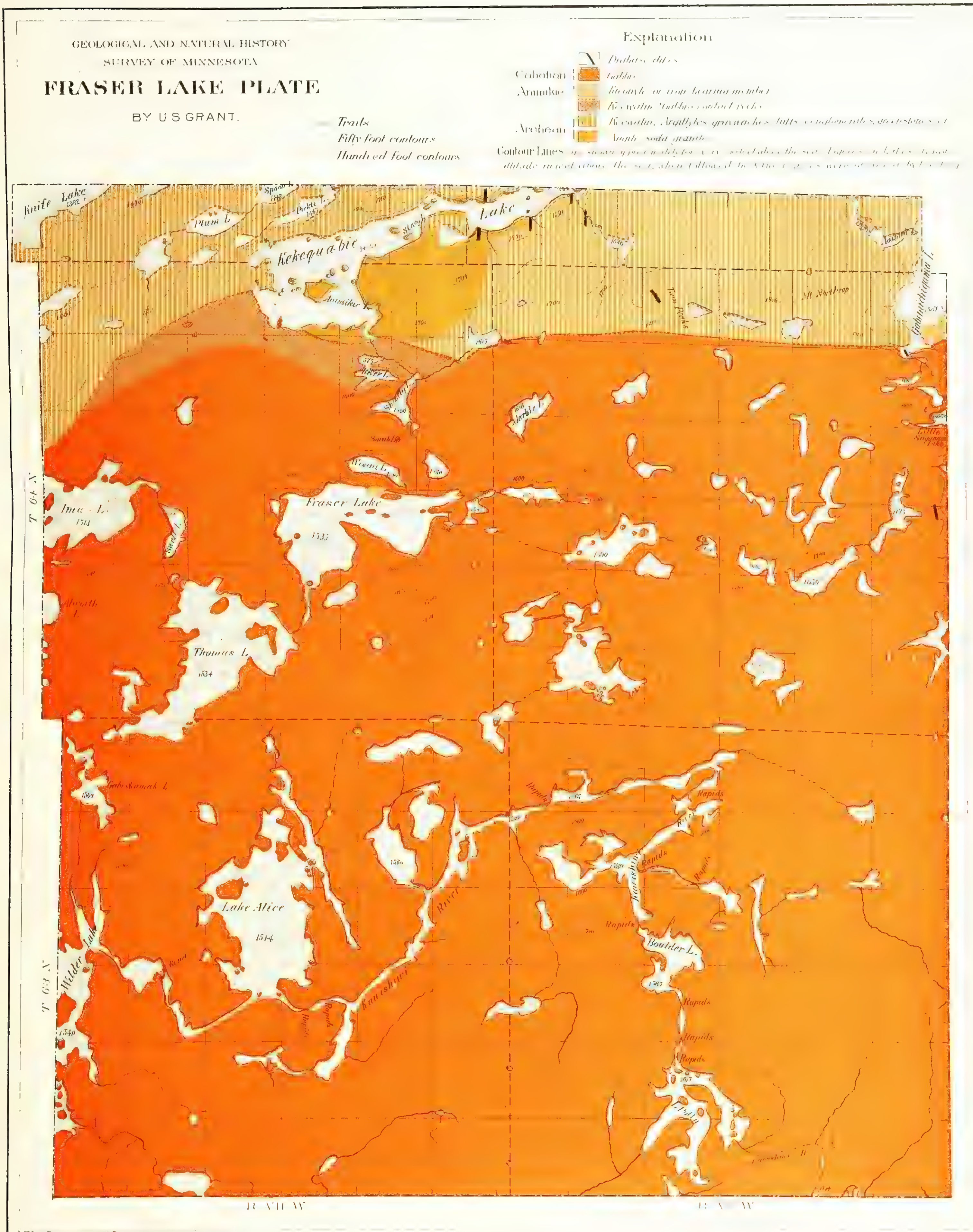
Situation and area. The Fraser Lake plate is situated on the northern part of the eastern border of Lake county and its northwestern corner runs to Knife lake, one of the international boundary series of lakes. On the east is the Akeley Lake plate (plate 81) and on the west the Snowbank Lake plate (plate 79). The Fraser Lake plate includes all of Ts. 63–6, 63–7, 64–6 and 64–7 W., and the south tier of sections of Ts. 65–6 and 65–7 W. It thus contains, including water areas, about 156 square miles. It is uninhabited, and, being removed from the usual canoe routes, is rarely visited, even by trappers and explorers.

SURFACE FEATURES.

Topography. The area here described contains two rather distinct types of surface, each being conditioned by the underlying rocks. The first of these types is represented by the gabbro-covered area which includes practically all of the plate except a belt on the north two miles in width. In general the surface of this area is in the nature of an undulating plain. Many small elevations occur, but few which rise to a hundred feet above the surrounding country. The most pronounced elevations in this plain are: (1) The hill in the S. ½ sec. 12, T. 64–6, west of Little Saganaga lake; this rises 200 feet above the lake. (2) The ridge in secs. 25 and 26, T. 64–7, which attains an altitude of 225 feet above Fraser lake. (3) The conical

* The area included in this plate has been examined at various times by different parties of the survey, and a considerable part of the field notes have been published. The individuals who did the work, the dates of the work, and the places of publication are as follows: N. H. WINCHELL, field work of 1879, *Tenth Annual Report*, pp. 96, 97; field work of 1886, *Fifteenth Annual Report*, pp. 360–369; field work of 1887, *Sixteenth Annual Report*, pp. 92–94, 99–108; field work of 1892, *Twenty-first Annual Report*, pp. 158, 159. A. WINCHELL, field work of 1886, *Fifteenth Annual Report*, pp. 145, 146, 170, 171. U. S. GRANT, field work of 1888, *Seventeenth Annual Report*, pp. 186–191; field work of 1891, *Twentieth Annual Report*, pp. 69–82; field work of 1892, *Twenty-fourth Annual Report*. Some features of the northern part of the plate have been described by the writer as follows: Note on an augite soda-granite from Minnesota, *Amer. Geol.*, vol. ii, pp. 383–388, June, 1893; Volcanic Rocks in the Keewatin of Minnesota, *Science*, vol. xxiii, p. 17, January 12, 1894; The Geology of Kekequabic Lake in Northeastern Minnesota, with special reference to an augite soda-granite, *Twenty-first Annual Report*, pp. 5–58.

On account of the monotonous character, in a geological sense, of at least three-fourths of the area,—that part being covered by gabbro of uniform nature,—and because the conditions are such that no important deposits of iron ore are likely to be found, this area was not examined along the Mesabi iron range as carefully as some of the other plates. The examination was confined largely to the lake shores, because this method furnished the most rapid and easiest means of determining the geological structure. Most all the lake shores, excepting those of some of the small lakes in the northern half of T. 64–6, were examined, and in a number of places, especially in the northern part of the area, the country away from the lakes was also visited. The writer, in 1891 and 1892, visited practically all the area which was examined by parties of the survey in 1886 and 1887, as well as examining many localities not before visited.


GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA
FRASER LAKE PLATE
BY U S GRANT.
Trails
Fifty foot contours
Hundred foot contours
Explanation
Cabotian
Animikie
Archean
Contour Lines
Knife Lake
Plum L.
Kekequabic
Lake
Fraser Lake
Thomas L.
Lake Alice
Boulder L.
Wilder Lake
Rapids
River
T 64 N
T 63 N

hill in sec. 17, T. 63–6 W., rising somewhat less than 200 feet above the adjacent parts of the Kawishiwi river.

While the surface is in general one of low relief, the minor irregularities are pronounced. Steep rocky hills are common and small vertical escarpments, ten to twenty feet in hight, are of frequent occurrence. The flat character is more pronounced in the southern than in the northern half of this gabbro-covered area. Some of the water bodies, none of which are deep, stretch through considerable areas, as for instance Fraser and Thomas lakes, which differ less than a foot in hight and extend into fifteen different sections, and the irregular part of the Kawishiwi river just east of lake Alice, which is nowhere more than half a mile wide and extends into twelve different sections.

The general plain-like character of the gabbro-covered area can be ascribed to weathering, erosion and glaciation acting on a surface composed of a single rock mass (the gabbro) uniform in constitution, grain and resistance to disintegrating agents. This comparatively featureless gabbro surface has been crossed from north to south in several places in Lake and Cook counties, and the difference between it and the country of more marked relief, both to the north and to the south, has been noted. And this country of more marked relief is composed of rocks different from the gabbro. The hilly country just to the south is made up largely of granites, while that to the north is composed of alternations of rocks of different nature. This fact of the existence of a character of surface, on either side of the gabbro area, different from that of the gabbro area itself can be seen more or less distinctly by examining the relations of topography to the underlying rock on this plate, and on the three to the east—the Akeley Lake, Gunflint Lake and Rove Lake plates (plates 81, 82 and 83).

In the Fraser Lake plate the belt two miles in width on the north shows the second type of surface. The underlying rocks here vary much in character, being composed of argillytes, green schists, grits, graywackes, conglomerates, greenstones and granites. Marked differences of elevation of the surface are characteristic of this area, the elevations being composed of rocks which best resist erosion and decay. Hills rising 200 or more feet above the surrounding country are common, and frequently these hills have steep or even precipitous sides. Such escarpments are seen on both sides of Kekequabic lake near its narrowest part.

The ridge running from Gabimichigama lake westward to the large southern bay of Kekequabic lake is part of the Giant's range, which in this distance shows several points rising considerably above the rest of the ridge. The hills in secs. 1 and 2, T. 94–7, are of granite and rise more than 250 feet above Kekequabic lake. A mile further east in sec. 6, T. 64–6, a hill composed of tough grit rises 100 feet higher,

and still further east, in sec. 4, T. 64–6, West and East Twin peaks rise 200 feet higher than the last. East Twin peak is the highest point in the area here described, being about 2,060 feet above the sea, over 560 feet above Kekequabic lake and about 678 feet above Knife lake (1,382 feet above tide), the lowest point in this area. Mount Northrop, in sec. 2, T. 64-6, is over 1,950 feet above the sea; this and the Twin peaks are composed of greenstone. On the north side of the central part of Kekequabic lake are some sharp ridges composed of volcanic tuff. One of these, in sec. 35, T. 65–7, is 260 feet above the lake; and another (Mallmann's peak) just outside the area of this plate, in sec. 30, T. 65–6, is 230 feet above the lake. The hights of the various lakes can be ascertained by consulting the map (plate 80).

The lakes in the gabbro area are comparatively shallow, and, from imperfect data, it would seem that depths of forty feet are uncommon. The lakes in the other area, especially Knife and Kekequabic lakes, are much deeper, and probably in places the bottom is nearly a hundred feet below the lake level. This will give a difference of about 778 feet between the extremes of elevation in the area of this plate.

An estimate of the average elevation, the highest and lowest points, and the difference between the extremes of elevation in each township, is given below. The figures refer to altitudes in feet above sea level, and the lowest lake surface is taken as the lowest point in each township.

	Average.	Highest.	Lowest.	Difference.
T. 63–6,	1,625	1,810	1,560	250
T. 63–7,	1,575	1,665	1,540	125
T. 64–6,	1,710	2,060	1,548	512
T. 64–7,	1,565	1,760	1,430	330
T. 65–6,*	1,650	1,855	1,498	357
T. 65–7.*	1,510	1,760	1,382	378

Drainage. The Fraser Lake plate lies in the drainage basin of Hudson bay, but the various parts of the plate belong to several minor basins. The waters of the small lakes in the eastern part of T. 64–6, Little Saganaga and Gabimichigama lakes flow through Agamok lake and then north and eastward to Saganaga lake on the international boundary. The waters from this lake flow westward along the north side of Hunter's island. Fraser and Thomas lakes outlet through Ima lake, and the water finds its way to Basswood (Bassimenan) lake, also on the international boundary. The lakes and streams in Ts. 63–6 and 63–7 and those in the southwestern part of T. 64–6 form what is known as the Kawishiwi river, which flows westward to the west edge of Lake county, and then northward to Basswood (Bassimenan) lake. The waters of Basswood (Bassimenan) lake join those from Saganaga lake in Lac la Croix at the west end of Hunter's island. The waters of the last mentioned lake eventually find their way into Hudson bay through the Rainy and Nelson rivers.

*Including only the southern tier of sections in this township.

The drift; a driftless area. The following directions (referred to the true meridian) of glacial striæ have been noted within the area of this plate:

S. W. ¼ N. E. ¼ sec. 32, T. 65-6, east side of old beaver pond,	south 25° W.
Sec. 18, T. 64-7, north shore of Ima lake,	south 23° W.
Sec. 18, T. 64-7, north shore of Ima lake,	south 36° W.
Sec. 28, T. 64-7, island in Thomas lake,	south 25° W.
Sec. 11, T. 64-7,	south 30° W.

These indicate a general south-southwesterly direction for the last glacial movement in this area.

The drift features of this plate have not been carefully studied, but a few points of interest have been noted. Throughout the area of this plate the drift is scanty, being sometimes practically absent or only a few inches, or feet, in thickness. The underlying rock outcrops abundantly, and in places continuous outcrops of considerable extent are seen. These rocks have suffered practically no decay since glacial times, but glacial striæ are not as abundant as might be expected, although the general rock surface presents the appearance of rounded glaciated domes. The highest hills have the same rounded appearance, and on the top of East Twin peak, as on other summits, foreign boulders occur. No morainic accumulations have been traced within the area of this plate, but in sec. 12, T. 64-7, are some drift hills which perhaps represent morainic deposits.

The shores of Wilder lake have been described as composed of gabbro decaying into soil, and free, or nearly so, from any foreign boulders.* This same peculiarity is noticed about lake Alice and more markedly in the southwest part of T. 44-6, and the northwest part of T. 63-6. The following extracts from field notes give more definite localities.

On the portage running northwest from the large lake in sec. 20, T. 64-6, are many outcrops of coarse gabbro, much decayed, and in places forming considerable soil. Very few smooth, fresh gabbro surfaces are seen. No large boulders occur, but there are a very few small boulders of slate and granite. The whole presents the same appearance as described about Wilder lake. The large lake in sec. 20, T. 64-6, is surrounded by gabbro hills, all decaying and forming soil. The lake in section 32 of the same township also has its shores of decaying gabbro. On going directly south from this lake to the Kawishiwi river in the southern part of sec. 5, T. 63-6, gabbro is seen in many places, often very much decayed; almost no foreign boulders were noted. Along the Kawishiwi river north of lake Polly, especially in secs. 7 and 8, T. 63-6, the gabbro is crumbling and decaying. Only a few foreign boulders, and these of small size, were seen. But one peculiar circumstance is that smooth and sound gabbro bosses occur within a few yards of other exposures of gabbro which is much decayed. However, on the smooth, undecayed bosses no glacial striæ could be found. The shores of lake Polly show somewhat similar decaying gabbro outcrops, but these are not so abundant nor so noticeable as at the localities mentioned above.

The differences between this region and the surrounding country are marked and consist in the following: (1) The lack, except for a very few foreign boulders, of drift, while the surrounding country contains many foreign boulders and frequently a thin covering of drift. (2) Glacial striæ have not been found, but are rather frequent outside of this area. (3) The rock is weathering and forming soil *in situ*, while elsewhere practically no rock weathering has taken place, and none

*N. H. WINCHELL. *Fifteenth Annual Report*, p. 350. See also chapter on Snowbank Lake plate, of this volume.

of the soil is formed directly from the underlying rock. (4) Sand beaches composed of yellow sand derived from the feldspar of the gabbro are common along the lake shores, but in the surrounding country sand beaches are of very rare occurrence.

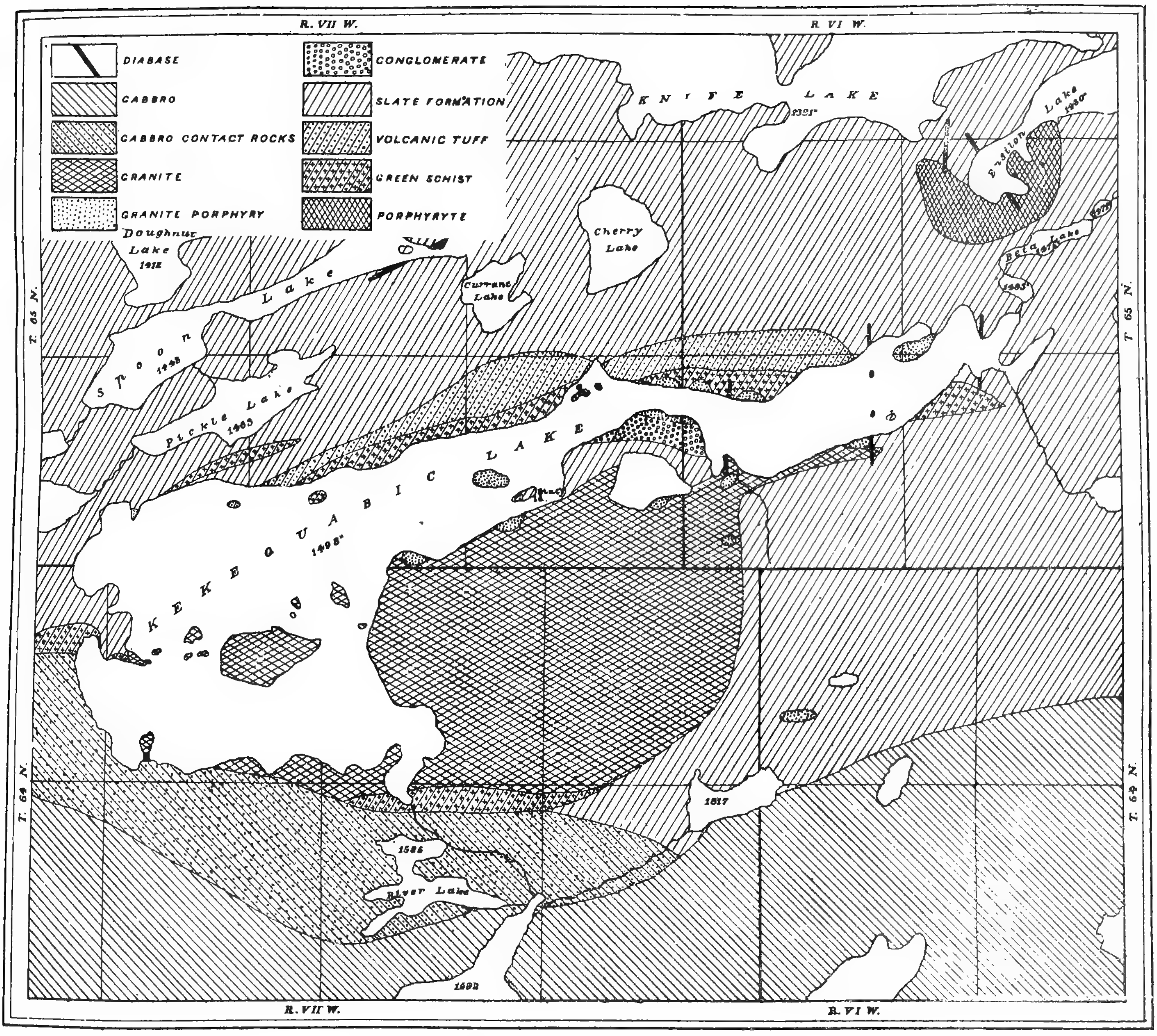
The marked weathering of the gabbro just described, judging from our knowledge of the lack of postglacial weathering in northeastern Minnesota, undoubtedly is not postglacial. That the area here described suffered no, or almost no, glaciation during the last Glacial epoch, is clear, but why it was not subjected to the same action which, in immediately adjacent areas, removed all the decayed rock, rounded the surface and deposited a slight amount of drift, is not so clear. It is possible that the high ridge, already mentioned, lying along the north side of T. 64–6, had some influence in modifying glacial erosion and deposition in the district here described. The poorly glaciated area is in a general south-southwest direction from this ridge—corresponding with the direction of last ice movement in this vicinity.

GEOLOGICAL STRUCTURE.

Brief sketch of the rocks. Following the divisions of the plate already noted—a northern part two miles in width, and another part including the rest of the area—we find that the first is underlain by rocks of Archean age. These are largely of clastic origin and are divisible into several groups. They include argillyte, grit, graywacke, green schist, greenstone, volcanic tuff and conglomerate. They have been closely folded, often rendered schistose and now stand in various attitudes, but have a general east-northeasterly strike. Associated with these rocks is a considerable mass of granite, also of Archean age, and all have been cut by diabase dikes. The second divison is underlain by a vast mass of igneous rock (gabbro) of much later date than the Archean rocks. Between these and the gabbro is a series of rocks not yet carefully studied, which are described as gabbro contact rocks. In a few places the gabbro includes small areas of iron-bearing rock of Animikie age.

The Archean. Rocks of this age occupy the northern two miles of the area of this plate, but on the western edge of the plate they extend a mile and a half farther south than elsewhere in this area. They are readily divided into two distinct and easily separable groups referred to Keewatin age; the first is composed in the main of clastic material; the second is granite.

In lithological character the Keewatin clastics are separated into five divisions, which, however, are not always sharply marked off from each other. These divisions are the slate formation, the green schists, the vulcanic tuffs, the greenstones and the conglomerates. While these general divisions can be easily made, still one sometimes grades into another, and our data will not allow us to map exactly the outlines of each division, although an attempt to do this is made in the accompanying map (plate LL), on which is represented Kekequabic lake and the adjoining country,



SKETCH MAP OF KEKEQUABIC LAKE AND VICINITY.

This map extends farther north than the limits of the Fraser Lake plate and includes one type of rock, a hornblende porphyryte, not represented in the area of that plate.

The strike of the Keewatin rocks varies considerably, but has a general east-northeasterly direction; the dip also varies, the rocks being closely folded, and steep inclinations of the strata are the rule. There is, at least, one marked exception to the general strike, and that is in the W. $\frac{1}{2}$ sec. 6, T. 64–6, where, for a considerable distance, the strike is nearly north and south, conformable to the edge of the granite mass on the west, and the dip is almost vertical.

The clastic rocks have been subjected to considerable dynamic action, and, as a result, all except the coarse conglomerate have acquired, in places, slaty and schistose structures. This is especially true of the argillytes and green schists, and in many places where undoubted stratification appears, it is practically coincident with the slaty or schistose structure. There are, however, many outcrops which show one of these secondary structures without exhibiting any distinct lines of sedimentation. And in this connection it should be stated that evidences of sedimentation are lacking over exposures of considerable size; this is especially the case in the conglomerates, tuffs, graywackes and grits, but is also true to a less extent in the argillytes. All of the clastic rocks, excepting the green schists and argillytes, are often seen possessing no evidence either of sedimentary lamination or of secondary parallel structures; in such cases the graywackes frequently present the appearance of fine-grained massive rocks.

(1). The slate formation. The larger part of the area shown in plate LL is composed of rocks belonging to this formation, which covers all the northern half of this area in fact the whole portion north of Kekequabic lake, except for small amounts of green schist, tuff and hornblende porphyryte, is underlain by the slate formation. It also occupies the eastern side and all of the southeastern quarter of the map (plate LL), but does not occur in any amount in the southwestern quarter. These rocks reach a great development outside of the immediate vicinity of Kekequabic lake, and form a large portion of the Keewatin rocks in Minnesota.

Lithologically the slate formation is divisible into three parts: argyllite, graywacke and grit. The first covers some areas almost exclusively, but the others, while found in large amount, are never entirely free from bands of argillyte. Still there are certain portions of the surface where grit or graywacke is developed to almost the complete exclusion of the argillytes. These three types of rock are found grading into each other. This is especially noticeable in the case of the graywackes and argillytes, the finer-grained slaty facies of the former passing by indistinguishable steps into gray argillytes. In mapping it is of course impossible to separate areas of argillyte from those of grit or graywacke, as they are frequently so intimately inter-

bedded, but under the description of each is given its distribution in areas where the two others are largely absent.

Argillyte. The larger part of the region north and west of Kekequabic lake, and also a considerable part of sec. 6, T. 64–6, is occupied by argillytes. They are found in their best development, comparatively free from bands of grit and graywacke, just to the west and northwest of Kekequabic lake and around the shores of Epsilon lake. In color the argillytes are generally rather dark, nearly black or dark gray, but they often vary towards greenish and lighter gray tints, and in one place, near the corner of the bay, in which is Stacy island, to a reddish shade. Evidences of stratification are quite generally present, being shown by alternating bands of lighter and darker shades and slightly different composition, these bands being usually from one-quarter of an inch to an inch in width. Rarely there are seen areas of the darker slates where sedimentary lines are obscure or entirely lacking. The darker varieties show the best developed slaty cleavage, but in no place is this continuous and perfect enough to make the beds of economic importance.

The argillytes vary in composition in two general directions. First, by the addition of more and more siliceous matter they grade into siliceous schists; variation in this direction is marked by a change in color to lighter and lighter gray. When the silica becomes more abundant, and is in distinct grains, the rock is approaching the graywackes and grits. Variation in the second direction is due to the addition of a chloritic or hornblendic (actinolitic?) constituent often accompanied by an increase of silica; the rock thus assumes a greenish color and a less cleavable character. Such green slates are tough and very hard. In one place, near the southeast end of Pickle lake, there are narrow bands of red and black jaspilyte interbedded with these green slates. These jaspilyte bands are the nearest approach to iron ore in the immediate vicinity of Kekequabic lake. Another direction of change for the argillytes is toward sericitic schists. This variation is not seen commonly at Kekequabic lake, but is shown to some extent.

Graywacke. This rock occurs in its best development around the east end of Kekequabic lake. It is seen in especially fine exposures in S. W. ¼ sec. 29, T. 65–6. It varies in grain from quite coarse graywacke, with quartz grains one-sixteenth to one-eighth inch in diameter, to a very fine gray slate. The coarser facies occur in massive beds from a few inches to many feet in thickness, and often show no parallel structures, either original or induced.

Grit. This rock is especially developed on the north slope of the hill whose summit is in N. ½ sec. 6, T. 64-6. It is very intimately interbedded with narrow bands of a greenish gray, very fine-grained rock. The beds of grit vary from a fraction of an inch to over fifty feet in width, and, aside from the interbanded gray rock, show no sedimentary lamination nor slaty cleavage. The grit is dark gray to black in color, rather fine-grained, and shows numerous glistening quartz grains and a few feldspar grains imbedded in a dark groundmass. These grains of quartz and feldspar and rock fragments (to be mentioned below) are usually from one-half to two millimeters in diameter,—often smaller and rarely larger. Under the microscope the rock is seen to be composed of sub-angular fragments of quartz and feldspar imbedded in a groundmass, which is made up almost entirely of green hornblende. The hornblende occurs in fibers and irregular grains. The fibres often are of minute size and penetrate the rock mass in all directions; they even seem to extend for short distances into certain quartz grains. Small fragments of various igneous rocks are also present, noticeable among which are a porphyryte and a fine-grained granite porphyry very similar to the porphyritic facies of the granite of this region, but showing no augite. The grit thus appears to have been deposited in water during explosive volcanic action, its material in considerable part being referable to such an origin. The groundmass, which has now crystallized as green hornblende, and the fine greenish gray bands in the grit, perhaps represent the finer parts of water assorted volcanic ash.

(2). Green schist. Within the area under consideration there occur certain green schists of a rather anomalous character. They are of a dull green color and are rather soft, crumbling easily under the hammer. These rocks have been often described in the reports on this region as "soft green schists" and "chloritic schists," but, as is shown below, they are essentially composed of hornblende.

These schists are found well developed in some places. A small belt occurs just north of Kekequabic lake, in E. ½ sec. 34, T. 65–7; also at the west end of the lake, in N. E. ¼ sec. 4, T. 64–7, along N. ½ sec. 11, T. 64–7, and on the south shore, in N. W. ¼ sec. 32, T. 65–6. But by far the most typical and interesting exposures are to be seen in a narrow belt along the north shore of the lake, in secs. 35 and 36, T. 65–7, and N. W. ¼ sec. 31. T. 65–6. Perhaps the best of these exposures occur on the small islands near the centre of section 36.

These outcrops almost everywhere show a distinct schistose structure, which is more pronounced where the rock has weathered. There are also in many places clearly defined lines of sedimentation; these can be seen in great perfection on a little island in S. W. ¼ sec. 35, T. 65–7. And here, as well as at some other localities, there are numerous rounded green pebbles of about the same composition as the green schist. These pebbles are clearly brought out by weathering and wave action, being slightly more resistant to these agencies of destruction than the rock itself, which decays and crumbles readily. There are also occasionally seen quartz pebbles arranged in parallel lines, thus giving additional traces of original sedimentary planes.

The green schist is usually of rather fine grain and is sometimes so fine that it appears homogeneous. In the coarser varieties it macroscopically seems to be composed of small, glistening flakes in an unindividualized groundmass. Under the microscope the rock is seen to consist of closely crowded green hornblende crystals imbedded in a fine fibrous groundmass. These hornblendes are usually in short stout prisms, but little elongated in the direction of the vertical axis. They are rarely more than half a millimeter in length, and the average is not more than half this size. The groundmass is quite fine and is composed almost entirely of interlacing fibres of hornblende. The original nature of the green schist is not very evident. That it is, in part at least, a water deposit, is, however, clear. As already mentioned it often shows distinct sedimentary lamination and the laminæ are frequently seen, where the rock has been more or less crumpled, running in wavy lines at various angles to the schistose structure. The difference between the laminæ appears usually only on weathering, as some are more resistant than others. One thin section cut across the lamination and schistosity, where these are parallel, shows many cross sections of hornblende, thus proving that a considerable number of the hornblende crystals have their vertical axes lying approximately parallel to the schistose planes of the rock. To the cleavage of these crystals is due, at least in some measure, the schistose structure of the green schists. This section also shows two laminæ, the only difference between them being that in one the hornblendes are noticeably larger, and that there is a small amount more of the saussurite substance than in the other. It seems improbable that the fresh and sharply outlined crystals of hornblende should have been deposited in that state, and so the rock appears to have been entirely recrystallized from its original condition.

As to just what was the nature of the original sediment which formed the green schists, it is impossible to decide, but it seems probable that it was a fine water-deposited volcanic ash, now entirely recrystallized. This idea is strengthened by the fact that these green schists are rather intimately connected with the next rock type, an undoubted tuff, and the two grade together; and in the latter are also found similar crystallizations of hornblende.

(3). Volcanic tuff. Extending along the central part of the north shore of Kekequabic lake, and separated from the water by a narrow belt of green schist, is a prominent ridge, ending on the east in Mallmann's peak. This ridge is made of hard tough rock, which, excepting at its eastern end, is different from any rock in the vicinity. It varies much in general appearance, but is usually of a greenish color with an aphanitic base in which are seen numerous lighter blotches and changes of color. Between these blotches, and sometimes in them, are black crystals of hornblende. Pyrite is also quite commonly seen. In certain places rounded and subangular pieces of quartz and argillyte are embraced in the rock, and it is also seen grading into the green schists. Parallel bandings similar to sedimentary laminæ also occur, sometimes quite abundantly, but usually the rock shows no structural planes of any kind, nor any schistose or slaty cleavage.

In thin section this rock varies much, but its fragmental character is easily discernible. The original nature of the fragments, which are usually angular, is, however, not very evident, owing to alteration and the development of secondary minerals in the rock, but it seems that a porphyryte forms most of these fragments. Between the fragments and forming the groundmass of the rock, and often in the

fragments themselves, are many hornblendes similar to those in the green schist. And there are also areas of secondary hornblende filling in old crystal outlines. What these crystals originally were is not clear, although they probably were pyroxenes.

(4). Greenstone. It is convenient to continue, at least for the present, this field term. It is applied to a series of greenish, more or less altered, rocks which are common in this part of Minnesota and which are known to be composed essentially of material of igneous origin. Frequently these greenstones are quite schistose and are then called greenstone schists, but in the area of this plate the schistose character is not so pronounced as elsewhere, and the greenstones form hard, massive, enduring rocks. The highest hills in the Fraser Lake plate are greenstone hills—mount Northrup and the Twin peaks. This rock is confined largely to the vicinity of these hills and occupies practically all the Archean area in secs. 2, 3, 4 and 5, T. 64–6.

While the greenstones are composed almost entirely of igneous material, it is as yet impossible for us to map the two parts of the greenstone areas, on account of the alteration which these rocks have undergone, and on account of lack of detailed examinations both in the field and in the laboratory. These two parts are: (1) A fragmental portion composed of fragmental volcanic materials, sometimes, though not always, showing evidences of deposition in water; and (2) Actual flows and intrusions of igneous rock. In general, these greenstones are basic rocks, and some of the less altered outcrops of the second part show that the rock at these places was originally a diabase.

(5). Conglomerate. While conglomeratic areas of very limited extent, holding only small pebbles, are found at various places in the rocks already described, especially in the green schists, still these areas have not been called conglomeratic areas. Conglomerates occur in characteristic development on the south side of Kekequabic lake between the shore of that lake and the small lake in S. W. ¼ sec. 36, T. 65–7. Here the rock contains well rounded and closely crowded pebbles which often reach a size of over a foot in diameter. These pebbles are of various rocks, including vein quartz, argillyte, jaspilyte and a granitic rock resembling the granite of this vicinity.

Another conglomeratic area is found near the southwestern corner of sec. 6, T. 64–6, just before the Archean rocks disappear under the gabbro mass.

The granite. The granite of Kekequabic lake is of a peculiar type—an augite-soda granite. It has been described at some length in the twenty-first annual report, and the following discussion of the general relations of this rock are taken from that report:

The granite, with the two exceptions mentioned below, is confined to a roughly oval area, whose major axis (east and west) is about three and a half miles; the minor axis being less than two. It occupies most of the S. W. ¼ sec. 31, T. 65–6 W., the S. ½

S. ½ sec. 36, T. 65–7, nearly all of sec. 1, all the land in sec. 2 and most of the land in sec. 3, T. 64–7. The only exceptions to the oval outline of the area occupied by the granite are: (1) A narrow band of granite, or what appears to be such, running out from the main mass along the south shore of Kekequabic lake in sec. 31, T. 65–6. (2) Small isolated granitic bosses found in the clastic rocks, mostly to the north of the main mass of the granite. The rock of these areas makes up the porphyritic facies of the granite. In this connection, and before proceeding farther, it might be well to state that the granite is separated into two principal facies—a granitic and a porphyritic—which are rather distinct in the field.

On all sides, except at the southwest, the outlines of the granite area can be pretty definitely traced, and we can feel sure that its surface area is about all exposed. But at the southwest the gabbro contact rocks come up to the granite. If these rocks are part of the gabbro which extends over the old granite surface, it is possible that there is an area of granite now concealed under the gabbro and its contact rocks to the southwest. But this is rendered rather improbable for two reasons: (1) The general outline of the granite area, and the fact that the clastic rocks of the region are found both on the south and west, would seem to indicate that they were continuous around the southwestern edge of the granite boundary. (2) It is not yet certain that the gabbro contact rocks which here come up to the granite are not the clastics of the region metamorphosed. There are no other known exposures of granitic rocks within several miles of the Kekequabic Lake granite, excepting one small outcrop (syenyte) in the midst of the gabbro near the centre of the S. W. ¼ sec. 11, T. 64–7.*

Parallel structures. One of the first features of the granite which attracts attention is its separation along roughly parallel planes. The layers thus formed vary from an inch to ten or more inches in thickness, and the same layer varies in thickness within a short distance. No difference in petrographical character between the different layers can be made out, nor is there any arrangement, macroscopically visible, of the constituent minerals of such a kind as to cause splitting along these planes. And there seems to be no tendency toward an indefinite separation into finer and finer layers. In some cases small quartz veins are to be seen between the different layers, but usually there is nothing visible except a simple undulating crack. Thin sections of the rock cut at right angles to this cleavage show no evidence of any parallel arrangement of the minerals nor of any microscopical faults or fault breccias, to which cause the rifting of certain granites is due.†

The cleavage of the granite of Kekequabic lake has been described and figured,‡ but no explanation of its origin was given. It was provisionally called flowage structure, but there is no evidence of such a structure in the rock. It seems to the writer this separation into sheets is probably due to jointage caused by contraction in cooling. While this cleavage is in places very pronounced, it is still not to be seen over most of the granite area. It is found in its best development on some of the smaller islands in the western part of Kekequabic lake, in sec. 3, T. 64–7. Here the parallel layers dip toward the north at angles varying in different outcrops from 10° to 40°, but on the little point in the S. E. ¼ S. W. ¼ sec. 2, T. 64–7, the dip is toward the south 10° to 15°. No general direction nor regularity in this dip has been seen.

It will be noticed that in the previous descriptions of this granite, it has been frequently called "fine syenitic gneiss," "chlorite gneiss" or simply "gneiss,"§ thus implying that there was some evident gneissic structure in the rock. However, aside from that described above, the writer has been able to detect no evidence of any parallel structures in the rock; there are no alternating bands of different mineral composition, nor are

* *Twentieth Annual Report*, p. 69.

† R. S. TARR. The phenomenon of rifting in granite. *Amer. Jour. Sci.*, iii, vol. 41, pp. 267-272, April, 1891.

‡ *Fifteenth Annual Report*, pp. 361, 362, figures 51 and 52. *Twentieth Annual Report*, pp. 70, 71, figure 5.

§ *Fifteenth Annual Report*, pp. 361-369. *Sixteenth Annual Report*, pp. 149-156.

the mineral grains uniformly elongated in a common direction. Wherever examined the rock presents a truly massive aspect. The only thing to suggest a parallel arrangement of the minerals is in small areas of the porphyritic facies of the granite, where some of the feldspar phenocrysts are arranged with their long axes roughly parallel, due to movement in the mass before solidification, and after the formation of the phenocrysts. In support of the above statements concerning the absence of gneissic structure in the granite, it may be well to quote the following from Prof. N. H. Winchell's second report on Kekequabic lake: "This [the granite] has been called *gneiss* this year and last, but it needs a word of qualification. It has not the real gneissic structure or foliation supposed to be due to original sedimentary bedding. It has acquired a sheeted structure, but in general it is a massive rock, showing variations due to the original conglomeratic state of its materials, as already described. Where it passes into the porphyry it is more compact and more firm than when it is not porphyritic."*

The only other parallel structure heretofore noted in the granite is that due to traces of an original sedimentary banding, considering the granite as a highly metamorphosed conglomerate. The remains of this structure were noted in one place, as follows: "There is visible sometimes not only a conglomeratic, but a sedimentary banded structure dipping 80° from the horizon, S. 10° W."† The writer can only say that he has been unable to find any traces of an original sedimentary banding in the granite.

Field relations of the granite to its own facies. As already stated, there are two important facies of the granite, a normal granitic and a porphyritic. The porphyritic facies occurs in isolated bosses without the limits of the granite proper, and is usually separated from it by the country rock. In a few places the two facies approach near to each other, but are not seen in actual contact. Here no evidence of a transition between the two is seen, each retaining its own characters as near together as they were exposed. Only one contact has been seen between these two facies of the granite; here in a small exposure branching vein-like forms of the granite porphyry cut the granitic facies. From this it would appear that the porphyritic facies is of some later date than the main mass of the granite. The two rocks agree so well in chemical and mineralogical composition, which will be mentioned later, that it seems impossible to consider them as anything but parts of the same magma. The writer is inclined to think that the porphyritic facies is of but little later date than the granitic facies and perhaps was erupted before the complete cooling of the latter.

In the N. W. ¼ sec. 2, T. 64-7, is a small island made up mostly of the normal granite, but with a porphyritic aspect. At the north end of the island is a dark gray to greenish rock, which has been termed the poikilitic facies of the granite, but there seems to be good reason for considering this as a part of the green schists of the region metamorphosed by the granite. This greenish rock is cut in all directions by vein-like forms of the granite and angular fragments of the dark rock are found imbedded in the granite mass. The granite where it cuts the other rock is of somewhat finer grain than at a short distance from this place.

A peculiar facies of the granite is found in the narrow strip which runs along the south shore of Kekequabic lake in the east half of sec. 31, T. 65-6. This is somewhat different from the normal granite, but nevertheless seems to grade into it. This facies of the granite is called the hornblendic facies.

Aside from the four phases of the granite already mentioned, there is another,—the syenitic facies. This is not as distinctly separated from the normal granite as are the others, but it forms an important part of the granite mass. In many places by a simple gradual loss of the quartz, the granite passes into an augite syenyte. These areas of syenyte occur most frequently on the hills in secs. 1 and 2, T. 64-7.

Field relations of the granite to the surrounding rocks. In former descriptions it has been supposed that this granite in places passes gradually into the graywacke and conglomerates of the region. At two localities there has been found a gradual passage from the granite to rocks macroscopically resembling fine graywacke or graywacke slate. The first of these is on the northern side of the narrow point which projects from the west shore of Kekequabic lake, in the S. W. ¼ N. W. ¼ sec. 3, T. 64-7. Here within a distance of thirty feet, there is a gradual transition from distinct fine-grained granite into a rock which resembles the graywacke slates of the region, but it shows no lamination and the slaty structure is not well developed. Near the base of the promontory in the S. W. ¼ S. W. ¼ sec. 29, T. 65-6, is an apparent transition in a distance of a foot or two from the phorphyritic granite to a graywacke-like rock. A series of specimens has been collected from both of these places, and mention of them is made in the section on the origin of the granite, but it may be well to state here that the microscopical examination in no way confirms the idea of a passage from a clastic rock to the granite.

Around the edge of the main mass of granite several exposures have been found showing contacts of this rock with the surrounding sediments. Perhaps the one best suited for the determination of the relations of the granite to the country rock is near the centre of the W. ½ S. E. ¼ sec. 1, T. 64-7. This locality is described beyond under the special descriptions.

The porphyritic facies of the granite is found in contact with the green schist and conglomerate in several places. It usually sends no apophyses into these rocks, but its later age is shown by its uniformly finer grain at the contact lines.‡

On a little point on the north shore of Kekequabic lake (S. W. ¼ sec. 34, T. 65-7 W.), the dark argillyte is cut by a small irregular dike of granite porphyry, which sends many stringers into the argillyte and also includes fragments of it.

* *Sixteenth Annual Report*, p. 104.
† *Fifteenth Annual Report*, p. 362.
‡ Two of these contacts are figured in the *Fifteenth Annual Report*, pp. 154, 367.

In the field there are seen to be two quite distinct facies of the granite—the normal granite and the granite porphyry. These present some microscopical differences, but they have many characters in common. The normal granite is of a medium or fine grain and a dull pinkish color. This color is quite characteristic of the rock as seen in most of the outcrops; it is due to the color of the feldspar, which is the predominating mineral. The texture is firm and compact. In some of the finer-grained phases it is almost impossible to distinguish any mineral other than feldspar, but in the coarser phases are also seen grains of a darker mineral, which proves to be augite, and quartz. However, the last is not very evident in hand specimens. In some places, noticeably in the N. W. ¼ N. W. ¼ sec. 2, and the promontory in the S. W. ¼ S. W. ¼ sec. 3, T. 64–7, the granite is sub-porphyritic with feldspar crystals. These phenocrysts are often, especially at their centres, of a little lighter color than the non-porphyritic feldspar. This granitic facies makes up the main mass of the granite; it varies little in different exposures.

The granite porphyry is found only in small isolated areas in the clastic rocks and near the edge of the area of normal granite. It is distinguished by its fine, usually aphanitic, groundmass and its decidedly porphyritic aspect, which is due to numerous white or flesh-colored feldspar phenocrysts scattered indiscriminately through the rock mass. There are also minute short stout augite prisms and occasional brilliant black biotite scales to be seen in the groundmass. The feldspar phenocrysts vary in size in the same hand specimen from almost microscopic dimensions to those ten or fifteen millimeters in length. The smaller ones are often very closely crowded together and are sometimes arranged more or less in lines of flow. At one locality these feldspars are very large and conspicuous, sometimes reaching a length of over twenty millimeters. The only exception to the white or flesh color of these phenocrysts is on the northern side of the small island in S. W. ¼ N. W. ¼ sec. 3, T. 64–7, where the feldspars are of a reddish color.

What is termed the hornblendic facies of the granite is found only in a narrow strip along the south shore of Kekequabic lake, in sec. 31, T. 65–6. It has a fine-grained gray groundmass whose constituent minerals are not readily distinguishable. In this are usually scattered small whitish sub-porphyritic feldspars and less evident black prisms of hornblende. This rock is different from the main mass of the granite in several respects, and the writer does not feel entirely satisfied that it is part of the granite, but it seems to be such and is placed here as a hornblende facies of the granite.

As already mentioned the normal granite is seen cutting a dark gray to greenish rock on the small island in the N. W. ¼ N. W. ¼ sec. 2, T. 64–7. This rock has a dull greenish groundmass in which are imbedded noticeable flakes of biotite

and less evident augite prisms. Even in hand specimens there are seen to be certain areas of the groundmass, each of which reflects the light, and in which are biotite and augite individuals. This rock has been called the poikilitic facies of the granite, but it seems more probable that it is part of the green schists of the region, metamorphosed and intruded by the granite. It is known only from the northwest side of this small island.

A noticeable feature of the granite in all its facies is the occurrence of small, rounded, subangular and angular areas, which are sharply marked off from the rest of the rock. They vary from half an inch to two inches in diameter, rarely being larger. They are composed usually of aggregations of rather coarsely crystallized hornblende or augite. Frequently, however, these dark areas are fragments similar to the country rocks—argillyte and green schist. These more or less rounded forms are very abundant in certain parts of the hornblende granite. In fact, in one exposure it is almost impossible to find any surface a foot square which does not contain one or more of them, and some areas of this size include as many as twenty.* In the granite proper and the porphyritic facies these rounded forms are not so abundant, still they are seen rather frequently. In the former reports on this granite these forms have been regarded as the remains of pebbles in a conglomerate, which was considered to be the original character of the rock, now a granite.† It also seems very possible to refer some of these forms to basic secretions, which are common to very many granites, while others, on account of their petrographical character, can be regarded as inclusions of fragments of the surrounding rocks.

Origin of the granite. In the reports on the geology of the region about Kekequabic lake, the granite has been regarded as of metamorphic origin. This has been maintained by Professors N. H. and A. Winchell, and from their reports it would seem that their ideas are as follows: The granite is a result of the recrystallization *in situ* under conditions of partial or complete aqueo-igneous fusion, of the sedimentaries of the region—the graywackes and conglomerates. The more or less rounded foreign pieces in the granite are the original pebbles of the conglomerate. The granite was in some places plastic enough to allow it to be intruded into the surrounding rocks, but this intrusion was only very local and limited in extent, and the intrusive rock was not moved far from its original place, The main mass of the rock has not been moved at all, but is simply portions of the graywackes and conglomerates altered *in situ.* There are gradations from the granite to these clearly clastic sediments and the granite is not sharply marked off from the surrounding rocks, except in the few places where it has been intruded into them.

The facts which are urged as sustaining the above idea as to the origin of the granite seem to be four in number, as follows: (1) Presence of ancient but partially obliterated lines of sedimentation in the granite. (2) Presence of pebble forms in the granite. (3) Transitions from the granite to the clastic rocks. (4) Presence, in the immediate vicinity, of altered clastic rocks resembling the granite.

In regard to the presence of old lines of sedimentation in the granite, or anything to suggest such lines, the writer can only say that he has been unable to see any such, although he has carefully searched for them. In fact he has seen no structures in the granite which could be referred in any way to old lines of sedimentation.

That there are numerous rounded, sub-angular and angular pebble-like forms in the granite has already been stated. These are more abundant near the edge of the granite mass and in the small bosses of granite porphyry; this is a significant fact and agrees well with the explanation that many of these foreign pieces are inclusions of the country rock. In fact, there is just as much reason (to the writer there seems more) for assuming that these pebble-like forms are basic secretions in the granite, or are inclusions of the country rock, as there is for assuming them to be the remains of pebbles in an altered conglomerate.

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* *Twentieth Annual Report*, p. 79.

† *Fifteenth Annual Report*, pp. 362, 368.

Two apparent transitions from the granite to a seemingly sedimentary rock have already been mentioned. In the field these transitions could be traced quite well, but the rock into which the granite graded, while resembling the sediments of the region, still could not be proved to be a clastic rock. A microscopical examination of thin sections of a series of specimens taken to illustrate these transitions shows that the apparent sedimentary end of the series and also all parts of it reveal no evidence of an original clastic nature, in fact their characters are those of fine-grained portions of the granite.* The conglomerate and graywacke, into which the granite has been supposed to grade, show in thin section undoubted clastic characters, and in all the sections examined there is no occasion to confuse these rocks with the granite.

A mile to the east of Kekequabic lake are found small areas of altered clastics, which, in some characters, resemble the granite. Here the remains of sedimentary planes are visible, and the rock in hand specimens and in sections is seen to be somewhat similar to the granite, especially as regards degree of crystallization. Rock like this is, however, not found in a position intermediate between the clastics, from which it is derived, and the granite, as would be expected to be the case. And it is well known that beds of certain altered clastics (gneisses) often closely resemble in hand specimens and in sections the granites which cut them, but this resemblance is no proof that the two rocks are of like origin and are parts of the same mass.

From the above it will be seen that the arguments for the derivation of the granite from the clastics of the region are, to say the least, rather unsatisfactory. Indeed, the facts seem as susceptible of explanation on the idea that the granite is eruptive as that it is a part of the altered clastics. Moreover, there are other facts which point very strongly toward the eruptive origin of the granite.

Contacts have been described which show that, at least at these localities, the granite plays an eruptive rôle. Here the granite has come into its present position in relation to the country rocks since their deposition, and it penetrates them in irregular dikes, and in one place includes undoubted fragments of the rock with which it comes in contact. Where contacts of the granite with the surrounding rocks occur the latter have been somewhat altered, although not very greatly, and a mass of the argillyte enclosed in the granite is rendered gneissoid near its edges. Contact metamorphism is, however, not very marked. At these contacts the grain of the granite is finer than at a short distance from the contact line.

That the granite is of a different character from the surrounding rocks is well shown by the ease with which it is separated from them. In no place has a gradation from any of the sedimentary rocks to the granite been established. In the field it has been possible to map the limits of the granite much more accurately and easily than any of the sedimentary rocks, the accuracy of the outlines of the granite depending only on the number of exposures to be found. No rocks intermediate in position or character between the granite and the clastics have been observed in the area mapped. The sharpness with which the granite is everywhere separated from the surrounding rocks is best seen where the porphyritic facies comes in contact with or is seen near the dark argillytes. This fact that the granite is everywhere so sharply and so distinctly separated from the surrounding clastics is a very weighty proof that it is not a part of these clastics.

It is easy to imagine sediments buried so deeply and under such conditions of pressure and temperature in the presence of water that they would be converted into completely crystalline aggregates. We have many such instances, and it is undoubtedly true that many gneisses were formed in this way, but here it is to be noticed that a degree of crystallization, as complete as in granites, is often attained without the obliteration of certain structural planes in the rock, *i. e.*, there are rapid alternations of bands of different chemical and mineralogical composition which are very distinctly separated from each other. Here there seems to have been practically no interchange between different parts of the mass. But if we assume that the granite under consideration, in which there are no alternation of bands of different composition, is of like origin, it seems necessary to assume that the fusion (if this word may be used) was so complete that the mass took on a uniform composition throughout, for it is hardly conceivable that a mass of sediments which shows a section three and a half miles long by two wide should be of a uniform composition throughout, and that this mass should be sharply separated, both along and across the strike, from sediments which do show this variation in composition. Moreover, it seems impossible that a mass which has been so completely altered *in situ* should be so sharply separated from the rocks from which it is supposed to have been formed and which still show their original clastic characters. Again, it seems impossible that the pebbles in a mass, which has been so profoundly altered and in which there has been so complete an interchange between its different parts, should not have been entirely obliterated instead of still retaining their own individuality. (It is to be noticed that the presence of so-called pebble forms is the chief point urged for considering the granite as altered sediments.) When fusion has gone so far as to allow a complete interchange of material between the various parts of the rock and an entire obliteration of all differences in composition between its various parts, and when such a rock is allowed to cool and crystallize as a holocrystalline mass, it is but a simple disagreement in terms that causes such a mass to be called anything but a truly igneous rock; and if such a mass is moved from its original position and forced into other rock it is truly irruptive in its nature and origin.

It is not necessary here to consider the question concerning the origin of granites in general; that question is almost as old as geology itself; it dates from the times of Werner and Hutton, and the writer cannot presume to discuss it. Nor is it necessary to say anything for or against the idea that some of the pre-Cambrian granites and granitoid gneisses may represent fused portions of ancient and very deeply buried rocks. But it can be stated that there seems to be abundant evidence that the Kekequabic granite shows no indication that it is an altered sediment, that it is not part of the clastics of the region altered *in situ*, but that it is truly eruptive in its origin and nature, that it has broken through the surrounding rocks in a truly eruptive manner, and that

*Compare rocks Nos. 601G to 605G, vol. v.

throughout its whole extent, now exposed to us, it is sharply separated from the surrounding clastics and is of later date than these.

It might be well to state that when the writer began the study of this granite area and two others in northeastern Minnesota he was inclined to the view that these granites were the altered clastics of the region, but even before the field work was completed and before the microscopic study of the rocks was begun, he was forced to abandon this idea.*

Special descriptions. A considerable mass of data have been collected from various places within the Fraser Lake plate, and below will be found, in condensed form, part of the field notes on the area underlain by Archean rocks.

Kekequabic lake. This lake is the most interesting in the whole plate, as about its shores centre many interesting problems in Archean geology, some of which are as yet unsolved. The lake itself is a beautiful sheet of water over four miles long, and varying from more than a mile to less than a quarter of a mile in width. In general it follows the direction of the rock structure, but the western part does not so closely conform to this direction as do the other parts of the lake. The eastern part of the lake, especially near its narrowest place, is deep, and the shores are precipitous, while the western part is more shallow, and the shores are not so rugged. The description will begin at the extreme southern point in the north edge of sec. 11, T. 64–7, and will run westward and thence around the lake.

On the southwest side of the bay in the above section is an outcrop of a fine-grained, dark gray granitic rock, speckled with small, flesh-colored feldspars (No. 1044). South of this outcrop and about 200 yards from the lake is an east and west ridge of a dark green, fine-grained rock containing much biotite (No. 540G). The granite is again seen on the south and on the west side of the small point in W. ½ S. E. ¼ S. W. ¼ sec. 2, T. 64–7. At the latter place is a considerable exposure of fine-grained granite (No. 771G) which presents an irregular layered appearance. The layers vary from an inch to ten inches in thickness. No difference in composition exists between the different layers, nor is there any arrangement of the constituent minerals in such a manner as to cause splitting along certain planes, and the rock shows no tendency to split up into an indefinite number of thin sheets, as does a schistose or slaty rock. In some instances minute quartz veins separate the different layers. Figure 74 represents the face of an exposure at this place and shows the regularity of the layers. The dip of this structure is 10° to 15° towards the south.

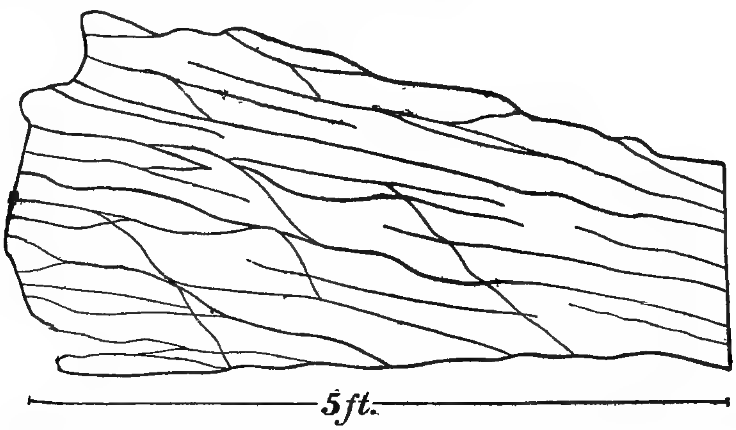


FIG. 74. SKETCH SHOWING THE PARALLEL LAYERS INTO WHICH THE GRANITE IS BROKEN. KEKEQUABIC LAKE.

The little promontory in the S. W. ¼ S. W. ¼ sec. 3, T. 64–7, consists of the granite in a fresh condition. This rock (No. 551G) has been taken as a typical representative of the Kekequabic Lake granite, and has been studied microscopically and chemically.† Here the rock again shows the layers described above, but this structure here dips northward 15° to 20°. At the base of this promontory is a low outcrop of a dark gray argillyte (No. 552G), the only outcrop of this nature known on the south side of the lake in its western part.

The greenish biotite rock is seen in several places along the west side of the lake, in S. E. ¼ sec. 4, T. 64–7. At one place it weathers out into pebbly forms at the water's edge (No. 1049) and overlies a small amount of argillyte, but so little of the latter is exposed above the water that the definite relations of the two could not be determined.

The only exposures of granite on the west shore of the lake are on the little point in S. W. ¼ N. W. ¼ sec. 3, T. 64–7. Near the base of the point, on the north side, is an outcrop extending along the shore for thirty-five feet, and just to the east smaller exposures occur within a few feet of each other. There appears here to be a transition (Nos. 601G to 615G) from the granite on the east to a fine-grained gray rock resembling some of the

* Compare Prof. Winchell's later discussion of the origin of this granite. *Structural Geology*, vol. v,

† *Twenty-first Annual Report*, pp. 33-54.

gray argillyte of this vicinity, but the fine-grained rock seems to be but a phase of the granite. These rocks are described in vol. v.

On the east shore of the little bay, which lies at the southern side of the base of this point, is a slaty rock, which, however, appears perfectly massive, except in weathered fragments where the slaty structure is brought out; no evidence of lamination was seen. At the northeast corner of this bay, the slate is a black, almost conchoidally breaking argillyte. Here on the weathered surfaces appears a fine lamination which strikes N. 20° E. and dips 75° toward the east. This rock is peculiarly spotted by small gray to whitish blotches. These spots are not very numerous, but are often quite distinct; they are of all sizes up to those five millimeters in diameter (No. 563G). Going west along the north shore of this little bay the black slaty rock is seen in several low outcrops; it is cut by small veins which stand out above the surface of the rock on weathered surfaces. Near the west end of the bay, in the S. E. ¼ N. E. ¼ sec. 4, T. 64–7, is a soft green schist (No. 564G), which strikes northeast and dips 70° toward the northwest. This rock shows no lamination, but has a very pronounced schistose structure. Just west of this, near the northwest corner of the bay, is the green chlorite-biotite rock.

In general, the islands in sec. 3, T. 64-7, are composed of the granite. The island nearest the little point above mentioned (S. W. ¼ N. W. ¼ sec. 3) has a bluff of granite near the centre. On the south shore is a dark green rock composed largely of hornblende (No. 561G), and it is in sharp contact with the granite. It is probable that the former rock is part of the green schist formation altered by the granite. The island just to the north of this has on its western end numerous loose angular fragments of a fine-grained, dark gray rock (No. 558G), holding many porphyritic crystals of red feldspar. And on the south side of the island, and in some places at its west end, are also fragments of a dark, conchoidally breaking argillyte very similar to that just mentioned. These rocks are undoubtedly in place just below the fragments. On the east end of the island is a small outcrop of a gray, fine-grained rock with porphyritic gray and pink feldspars and minute porphyritic augites. It is in sharp contact with the argillyte. The two porphyritic rocks are regarded as parts of the same mass, and as a porphyritic phase of the granite of the region.

On the west side of the point near the northwest corner of sec. 3, T. 64-7, are black and gray argillytes. The strike and dip are not clearly shown, but appear to be as follows: strike N. 35° E. and dip 65° to 70° to the east of this. On the south side of this point, at the entrance to the little bay, the same rock occurs, and the strike is distinctly north and south and the dip 55° towards the east. The bedding and the slaty cleavage here coincide in direction. On the south side of this bay the strike is the same, but the dip is steeper, as much as 70° towards the east.

The point on the east side of the bay, in E. ½ S. W. ¼ sec. 34, T. 65-7, is made of black and gray, hard argillytes, striking N. 60° E., and dipping 75° south of this. The bedding and slaty cleavage are parallel. The argillytes are cut by a small, very irregular dike of the porphyritic granite. The contact between the two is very sharp and distinct. The dike sends stringer into the argillyte and includes pieces of it. Along the shore east of this the same argillyte is seen again, but within a quarter of a mile a small amount of volcanic tuff appears. This apparently grades into distinctly laminated gray slates and also into the soft green schist.

The island near the east side of sec. 35, T. 65–7, is composed of volcanic tuff, while the island about half a mile east of this contains the green schist. The strike, which here coincides with the direction of the schistosity, is N. 75° to 85° E. and the dip is 90°. In places on this island the rock is pebbly, as is well shown on weathered surfaces, but on fresh fractures the pebbles can hardly be distinguished. The pebbles are largely of rock similar to the matrix, but a few of quartz and a gray slaty rock occur. On the islands just off the north shore, near the centre of N. ½ sec. 36, T. 65-7 W., the green schist is well displayed, and along the north shore east of these islands are cliffs of typical parts of the volcanic tuff.

On the north shore near the west line of sec. 31, T. 65–6, and at two places within half a mile east of this point, the porphyritic granite occurs in small bosses, apparently intrusive into the green schist. East of this, where the north line of this section cuts the shore, is Mallmann's peak, composed of the volcanic tuff on the south slope and of graywacke slates on the summit and eastern face. The point on which is the northeast corner of this section is composed of the porphyritic granite in typical development. Here are frequently small, rounded forms of greenish material, mostly augite and hornblende, in the rock. Near the base of the point there appear on weathered surfaces rough, angular or rounded forms of rock, apparently similar to the matrix, but less decayed. It would seem, perhaps, that here there has been some brecciation of the porphyritic granite. Sections from specimens collected here can thus be interpreted, although the rock approaches macroscopically some of the graywackes of the vicinity.

On the northwest end of the little point in S. W. ¼ N. W. ¼ sec. 31, T. 65–6 (south side of the lake), there is a dark, medium-grained diabase. And on the northeast corner of this point is a low outcrop of a fine-grained, gray, apparently holocrystalline, rock. The groundmass is grayish, and in it are small, black needles of hornblende and a few scattered, rather irregularly outlined feldspar individuals. There are also a few rounded pebble-like forms, of all sizes up to two inches in diameter, scattered through the rock. Some of these pebbles are seen to be sub-angular, but most of them are rounded. They seem to be scattered irregularly through the rock and lie in no definite planes or layers; there is nothing in the rock to show any sedimentary lamination or bedding; it appears perfectly massive. This rock is seen in several outcrops in the N. E. ¼ S. W. ¼ sec. 31, T. 65–6, and the shore is here usually lined with fragments of it. In the eastern part of this one-sixteenth section is quite an extensive exposure a short distance back from the shore. Here the pebbles, which have been steadily increasing in abundance eastward from the first mentioned outcrop, are very numerous. It would be almost impossible to find any surface a foot square in the rock at this place which would not contain one or more pebbles,

and many areas of this size would include as many as twenty. The rock is here represented by No. 594G and pebbles from it by No. 594aG. This rock extends along the shore in a few outcrops nearly to the east line of section 31. The pebble-like forms grow less abundant on going eastward and the rock is more coarsely crystalline (No. 595G). The noticeable features of this rock are its sharply outlined, rounded and sub-angular pebbles, and the few scattering, white, porphyritic feldspars sometimes a quarter of an inch in length. No bedding or any definite arrangement of the pebbles can be seen, and the exact nature of the rock is not clear.

About 150 yards south from the base of the little point mentioned in the last paragraph is an exposure of the porphyritic granite, which here contains larger porphyritic feldspars than elsewhere. On the west this rock is in contact with the ordinary granite. The relative ages of the two rocks are not clearly shown by one cutting the other, but from the fact that the porphyry is distinctly finer-grained at the contact than away from it the latter rock is considered the younger.

On the south shore of the lake at and west of the west line of range 6 are exposures of a coarse conglomerate underlain by porphyritic granite. Conglomerate also appears on the south side of Stacy island, which is the island nearest the south shore in N. ½ S. W. ¼ sec. 36, T. 65–7. From this island west and south to the extreme southern corner of the lake the granite occurs, except near the head of the little bay in N. E. ¼ N. W. ¼ sec. 11, T. 64–7, where the green biotite rock is seen. This same rock also occurs on the portage south to River lake.

An island in the N. W. ¼ N. W. ¼ sec. 2, T. 64–7, is composed largely of granite (No. 575G). It is in contact with a green rock (No. 574G) which shows many biotite scales. This latter rock is made up of large areas of feldspar in which are imbedded biotite and augite; it has been referred to as the poikilitic phase of the granite,* but the relations are such as to indicate rather that it is a condition of the green schist of the region, cut by the granite and entirely recrystallized.

Mount Northrop. This hill lies in sec. 2, T. 64–6, and was visited from Gabimichigama lake by Prof. N. H. Winchell, whose notes are as follows:

From a camp which we made on the west shore of Gabimichigama lake, just south and east of the high hill that rises from the lake shore, an ascent of this hill was made, and the rock was carefully examined at numerous places, and samples were taken at ten places (No. 1367), intended to show the average character. At the shore south of the hill (in the southwest bay, already noted) is a coarse, though greenish, conglomerate or grit. The same rock is found near the foot of the hill, and at intervals all the way to near the summit, but it becomes finer and finer, and cannot be distinguished in some cases from some of the finer beds of the Animikie. The whole aspect of the hill in its form, the strike of the main rock outcrops, the confused mingling of structure and texture, is that of an eruptive rock, whether from deep source or not. The color is dark, and at first glance it might be taken for a greenstone eruptive. These eruptive features are more pronounced near the top. Still, it is of a light green color, and scarcely a sample can be obtained which does not show some free rounded grains of silica. The whole rock appears somewhat siliceous. Some of it is dark blue, and fine-grained as argillyte. There are occasional rusty or irony patches, like the rusty patches seen in the Animikie at Gunflint lake. There are siliceous seams of the same color as the body of the rock, but much harder and finer, which on the weathered surface give a ridged reticulation like that which was photographed at the west end of Kekequabic lake last year (figure 3, plate KK). Reëxamining all the specimens, and comparing all the facts, I am convinced this hill is made up mainly of modified beds, but that they have been in almost a plastic slate, and probably toward the summit were mingled with a truly eruptive greenstone without free silica, and without traces of sedimentary structure and composition.

Ten samples (No. 1367) are intended to show the above mentioned sedimentary characters, taken from the southern slope in ascending.

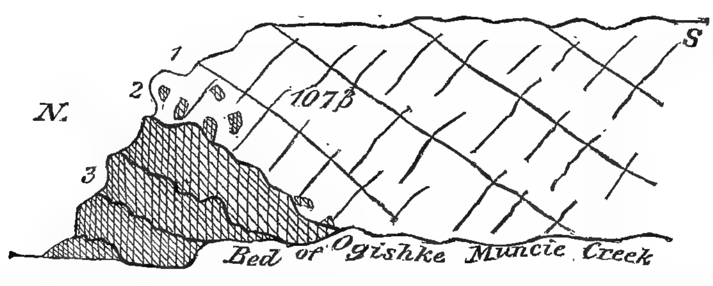


FIG. 75. DIAGRAM OF A SUPERPOSITION OF ROCKS AT THE MOUTH OF OGISHKE MUNCIE CREEK.

1—An overflowing rock, having the jointage, action and aspect of an eruptive rock (No. 1073).

2—Irregular stratum of the same, holding fragments of fissile, closely jointed slate which is thin and black, and crumbles in the slope, of which No. 1074 is a sample. Rock No. 1075 shows the contact of these two rocks, and the consequent blending of characters.

3—Fissile black slate, closely jointed, separated into thick beds, the upper and lower sides of which undulate, the general dip appearing to be southeast, but so faulted and twisted that it cannot be determined. The whole slate exposed is about fifteen feet, and the overlying rock rises about ten feet higher at the place of the diagram, but it spreads generally over the surface at some little distance back from the shore. It also extends westward, across the creek, and then spreads about over a distance of some rods, making some little hillocks. The slates underlying are highly changed, or brecciated, and uniformly converted to a very closely jointed or fissile, fine (cherty) rock.

* *Twenty-first Annual Report*, p. 50.

Three samples (No. 1368) show the nature of the summit, being a more homogeneous, darker, medium-grained, green rock, without very evident free quartz.

South of Ogishke Muncie lake. An ascent was made from the mouth of the creek in N. E. ¼ S. W. ¼ sec. 26, T. 65-6, to the hill which lies in the N. ½ sec. 35, T. 65-6. The observations taken here are so important, in that they seem to indicate an unconformity between the two parts of the Keewatin, that the notes and figures, as published by the state geologist,* are reproduced here. The rock (No. 1073) of figure 75 is not an eruptive rock, but is a clastic, probably representing the base of a series of rocks unconformable on the underlying black slate.

At the mouth of the stream which enters Ogishke Muncie lake from the south was taken the foregoing diagram (figure 75).

In going upward from here to the hills in sec. 35, T. 65-6, on the west side of the creek, the following facts were noted: (1) The sedimentary slates and quartzytes are broken, and dip in various, but nearly vertical, directions. (2) The sedimentary beds become porphyritic with feldspar crystals, and apparently with some quartz crystals. (3) They acquire a fluidal bedding, seamed and veined by quartz. (4) They strike N. 20° W., N., N. 28° W., N. 20° E., and generally dip east or southeast, or south, toward the mountain, but their strike on weathered surfaces is often contorted, like the graywacke at Tower, and fragments are mixed with other kinds of beds, the beds apparently bending round them. (5) So far as observed they are always full of free quartz grains, even in their apparently igneous outward aspects. The weathered surface is light-gray, or graywacke-like. (6) Further up, at three-fourths of a mile from the lake, the strike is W. 25° N., and the dip is 80° to 85° toward the south-west. (7) At the distance of nearly a mile from the lake, at 145 feet above it, the change illustrated by the accompanying diagram (figure 76) takes place. Here the sedimentaries dip north at an angle of 50° from the horizon, 40° E., lying on the greenstone illustrated by sample No. 1076. On the top of this hill are scattered boulders of Saganaga granite, etc.

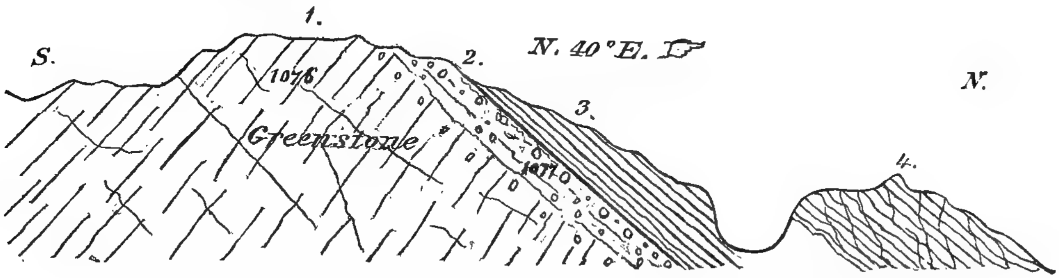


FIG. 76. SHOWING THE POSITION OF THE SLATES AND QUARTZYTES RELATIVE TO THE GREENSTONE ON SEC. 35, T. 65-6.

1—Greenstone, apparently forming the mountain to the south (rock No. 1076), at 145 feet above Ogishke Muncie lake. This rock is tough, massive, and coarsely jointed.

2—Pebbly greenstone, three to five feet (rock No. 1077). On the surface the line of contact, which, facing north, is glaciated, shows very distinctly, and the pebbles seem to be all of greenstone, or at least of some greenish rock, some of them quite fine-grained. The line of contact is shown by the above figure.

3—Hard, fine-grained, almost cherty, but black, beds of slate in distinct sedimentary arrangement.

4—Broken and contorted graywacke and slaty bed, seen about ten feet.

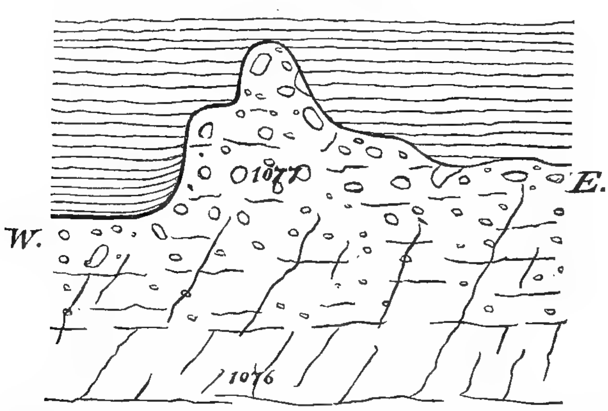


FIG. 77. PLAN OF THE SURFACE SHOWING THE LINE OF CONTACT AT FIGURE 76.

This superposition is believed to be accidental, and one of the local over-turn dips that accompanied the upheaval of the formation. The numerous other observations already given on the direction of dip of the quartzyte and slate series in this mountain show the frequent changes of direction to which it is liable. The

* *Fifteenth Annual Report*, pp. 372-374.

correct stratigraphic sequence will require the quartzyte and slate rocks below the gabbro—if not below this greenstone.

We ascended only to a spur of the main hill, rather lying between the two hills that are in section 35, 260 feet above the lake. The hill which lies about half a mile further south seems to rise about a hundred feet higher, or 350 feet above Ogishke Muncie lake. The same rock as No. 1076 continues to and forms that hill, as ascertained in 1879.

East Twin peak. The following notes on an ascent to this hill are from the sixteenth annual report, pages 99, 100:

From this point (west end of Ogishke Muncie lake, S. W. ¼ sec. 27, T. 65-6) an ascent was made, by Mr. F. N. Stacy, of East Twin mountain, and he reported substantially the following results. The position of the mountain was ascertained from magnetic observations on a common compass needle, as follows:

The north side of Little Saganaga lake is E. 10° S. (mag.)

Camper's island is N. 20° E. (mag.)

Lake Saganaga (a broad expanse of water) is N. 15° E. (mag.)

The mountain which lies at the west side of lake Gabimichigama (rocks Nos. 1367 and 1368), which is near the centre of sec. 1, T. 64-6, is about due east (mag.)

These directions place East Twin mountain not far from the centre of sec. 4, T. 64-6, nearly a mile further south, and half a mile further west than was represented on the geological map accompanying the fifteenth report.

The summit of the mountain is made of the rock No. 1386, a coarse hornblendic greenstone, resembling rock No. 759 (tenth report, page 97).

Near the top, but on the body of the hill, on the north side, was seen a finer greenstone (No. 1387); but further down (still on the north side), near the bottom of the hill, it is a coarser rock (No. 1388) of the same kind as No. 1387, but not so gabbro-like as No. 1386; but at the bottom of the hill are found both coarse and fine (No. 1389), the coarse being identical with No. 1386.

According to the observation made by Mr. Stacy this hill is set off abruptly, both topographically and lithologically, from the following, by a ravine, or series of irregular, branching valleys. The hill rises about 350 feet above this ravine. The rocks that constitute the lower hills on the north side of this ravine are in the main an ambiguous greenstone (No. 1390), and seem to be closely associated, perhaps blended into, the prevailing sedimentary rocks that are seen about the southwestern shores of Ogishke Muncie lake. These sedimentaries consist of siliceous slate, conglomerate, etc. This lower hill range hides the Twin mountains from sight, from Ogishke Muncie lake, except at the northeast end of the lake, and seems to be a connecting line between the Twin mountains and the hills immediately west of Gabimichigama lake. It lies not far north of the Twin peaks. Indeed, Mr. Stacy represents that the peaks are simply higher parts of a general hill range, cut off by ravines from the rest of the range, and that, in general, the fragmental rocks cease before reaching the ravine mentioned.

Rocks Nos. 1391, 1392, 1393, 1394 and 1395 represent the broken sedimentary rocks intervening between the peaks and Ogishke Muncie lake. No. 1393 represents several small hills, or hill ranges, a gritty greenstone, or modified sedimentary. No. 1394 is chalcedonic silica, and samples closely related, all enclosed in and banded together in No. 1393. These are in three small ridges, successively, but the samples are all from the same ridge. The chalcedonic silica seems to indicate the horizon of the Keewatin, and the iron ore here associated with it, although magnetite, does not preclude the parallelizing of this nearly with the horizon at Tower. No. 1395, which is a widely disseminated rock, is a greenish conglomeratic one, the same as seen in many places about Ogishke Muncie lake, a part also of the Keewatin, as already mentioned. It is filled with fragmental material, but takes the forms and basaltic habit of an eruptive. It seems to be made up largely, in some places, of broken masses of older strata, as well as of individual fragmental grains, the whole compacted together by a prevailing greenish, hornblendic matrix.

West Twin peak. Starting from the head of the bay in N. W. ¼ N. E. ¼ sec. 32, T. 65-6, a trip was made from Kekequabic lake southeast to West Twin peak. A little over an eighth of a mile from the lake a ridge of slate and fine graywacke is crossed. The strike is N. 37° E., and the dip 90°. Beyond this are other outcrops of slate and graywacke, becoming coarser and darker colored. Half a mile from the lake is an old beaver dam, on the west shores of which the rock is a rather coarse grit with some slaty bands. The strike is N. 30° to 40° E., and the dip 65° to 70° south of this. One hundred and fifty yards farther east is another pond also surrounded by grits with some slate. On the northeast shore is a vertical cliff showing an apparent northeasterly strike and a vertical dip, although neither was determined certainly. Here some of the grit (No. 785G) contains small blood-red fragments, perhaps of jaspilyte. The cliff is cut by a dike, ten feet in width, of porphyritic granite quite similar to that of Kekequabic lake. On the south shore of this pond considerable black slate is seen. Less than a quarter of a mile southeast from the last pond is a small lake which is thought to be the one crossed by the east line of sec. 32, T. 65-6. On an island in the eastern part of the lake the rock is hard, sometimes flinty, and sometimes conglomeratic (Nos. 1754 and 1755).

From the southeast corner of this lake an ascent was made to the summit of West Twin peak. The rock passed over is in general greenstone, varying considerably in character (Nos. 1756 to 1761), being sometimes coarse and sometimes of fine grain, again plainly fragmental, and again of the nature of altered diabase. At the summit a diabase dike, ten feet wide, cuts through the country greenstone. The dike runs northwest and southeast, and is very fine-grained at its edges.

South of Kekequabic lake in sec. 6, T. 64-6. A trip was made south from this lake to the summit of the hill in the N. ½ sec. 6, and from here southwest to the lake at the southwest corner of this section. At the shore

of Kekequabic lake, S. W. ¼ N. E. ¼ sec. 31, T. 65-6, the porphyritic rock which holds pebble-like forms (already mentioned, pages 449, 450, of this report) occurs. These forms become less numerous, but no less sharply outlined, on going south from the lake, and the rock becomes more coarsely crystalline and holds more of the porphyritic white feldspars (No. 630G). No evidence of bedding was seen in this rock. Beyond this, and within fifty yards of the last exposure of this rock, there are outcrops of slate. This slate varies from a dark, almost black argillyte to one that is quite light-gray. The lamination of the slate was twisted in some places, but as a rule this coincided with the slaty cleavage. The dip and strike were taken in many places before reaching the top of the large hill, whose summit lies in the N. E. ¼ sec. 6; the dip was vertical and the strike varied from N. 35° E. to N. 55° E. The slate was intimately interbedded with a dark-gray to greenish grit, but the lines between the two rocks were quite distinct. The bands of each varied from those a fourth of an inch across to those that were fifty feet or more in width. The grit held angular fragments of the slate and bands of the slate that were abruptly cut off; there were also places where bands of the slate were faulted and the grit existed between the faulted and broken ends of the slate bands. This grit makes up about half of the exposures to the hill top, but no exposure was composed entirely of this or of the slate alone. No. 631G is the black slate; No. 632G, the grit; and No. 633G shows, as well as a hand specimen can, the intimate interbanding of the two. At the top of the high hill the grit is coarser grained than usual, as is shown by No. 634G. The strike continues to be northeasterly until coming to near the centre of section 6, where it changes to N. 20° E., and a short distance farther south to direct north and south; the dip still remains vertical. This north and south strike continues to the pond which lies in N. E. ¼ S. W. ¼ sec. 6. No. 635G shows another condition of the grit resembling graywacke from just north of this pond. In this there is seen indistinct lamination, but the other specimens of the rock do not show it; the rock (grit) elsewhere appears perfectly massive except for its interbanding with the slates. South of this pond the strike again swings round to northeast and the dip remains vertical.

About a quarter of a mile south of this pond is an outcrop of a porphyritic rock which is probably the same as the granite porphyry of Kekequabic lake. About seventy-five feet of this rock was exposed, the slates occurring both north and south of it within less than 100 feet. The porphyry is No. 636G. The weathered surfaces of it show a rough schistose structure which runs N. 35° E. and stands vertical; however, this structure is not seen on freshly broken surfaces. The feldspar crystals are often arranged with their long axes parallel to the direction of the schistosity. The northeast strike of the slate and grit continues as far as they were seen, *i. e.* almost to the lake at the southwest corner of section 6. A short distance before reaching this lake the slate disappears, and the grit, similar to Nos. 632G and 635G, both of which facies here often show fine lamination on weathered surfaces, becomes in places conglomeratic and harder (No. 637G). The pebbles are mostly rounded, some few are subangular, and they are chiefly of slate and a reddish granite porphyry, a pebble of which is shown in the specimen collected. This conglomerate shows no signs of lamination or schistosity. A short distance further south, and almost at the lake shore, is a more crystalline conglomerate holding pebbles of the same or similar reddish granite porphyry, and also of a fine-grained red granite or syenyte which resembles the pyroxene granite already mentioned so often. This conglomerate is shown by No. 638G. In this rock, and also in No. 637G, the pebbles varied from quite small ones up to those eight inches in diameter, but most of them were one to three inches across. In some places the pebbles were quite numerous, and in others there were but a few to be seen. No definite arrangement of the pebbles in planes nor any elongation of them in one direction was seen.

The eastern half of the north shore of this lake has some outcrops of conglomerate represented by No. 638G. On the east shore of the lake there are no outcrops until coming about to the south line of section 6, where a fine-grained condition of the gabbro (No. 639G) occurs, and a little farther south the ordinary gabbro is found.

S. E. ¼ sec. 1, T. 64-7. The conglomerate mentioned above as occurring near the north shore of the lake at the southwestern corner of sec. 6, T. 64-6, also occurs farther west near the shore and extends into the S. E. ¼ sec. 1, T. 64-7. It is a tough, greenish, sometimes slaty rock, frequently entirely free from pebbles. The bedding cannot usually be seen, but the rock possesses a fine lamination, which in places where actual bedding was seen coincides in direction with it. The following dips and strikes refer to this lamination, which is possibly, though not certainly, coincident with the bedding.

Around the north end of the bay, at the northwest corner of the lake, are several outcrops of the same greenish rock (No. 739G) mentioned above, but here holding no pebbles. The lamination in these places strikes N. 75° E., and stands vertical. On the west shore of the bay is another outcrop of this rock, striking N. 55° E.; the dip is vertical. The same rock is seen in several places just west of the lake and one outcrop occurs at the extreme southwest corner of this lake. Here it is much metamorphosed, probably by the gabbro, and contains a few pebbles (No. 740G).

North from this lake, about on the east line of section 1, the rock becomes less crystalline and sometimes slaty. One-fourth mile from the lake the rock (No. 743G) has lamination and slaty cleavage coincident; strike N. 85° E.; dip 85° toward the south.

North of the extreme northwest corner of this lake the conglomerate is seen in several places not far from the shore. It is very hard and tough and the pebbles are not numerous, being sometimes lacking entirely. About one-eighth of a mile from the lake the strike is N. 70° E. and the dip 90°. The rock gradually becomes less crystalline on going north, and at one-fourth mile from the lake the strike is N. 40° E. and the dip 90°. Here a dike of diabase two feet wide cuts the country rock in a direction about parallel with the strike. About 200 feet north of this is an outcrop showing contact of the green slaty rock, which is the same rock as described above as conglomeratic, and the granite. The relations are shown by the accompanying plan of the surface (figure 78). The granite at the contact is of finer grain than away from this line.

North of this for a quarter of a mile are several exposures of the granite. In less than this distance eastward from the last point the slaty rock occurs again, but just west of the last rock the granite is finer grained. The first exposure of the slaty rock seen here contained two irregular vein-like forms of a fine-grained rock, apparently part of the granite. Fifty feet east of this the slaty rock strikes N. 30° E. and stands vertical. A short distance towards the southwest another contact of this slaty rock and the granite is seen.

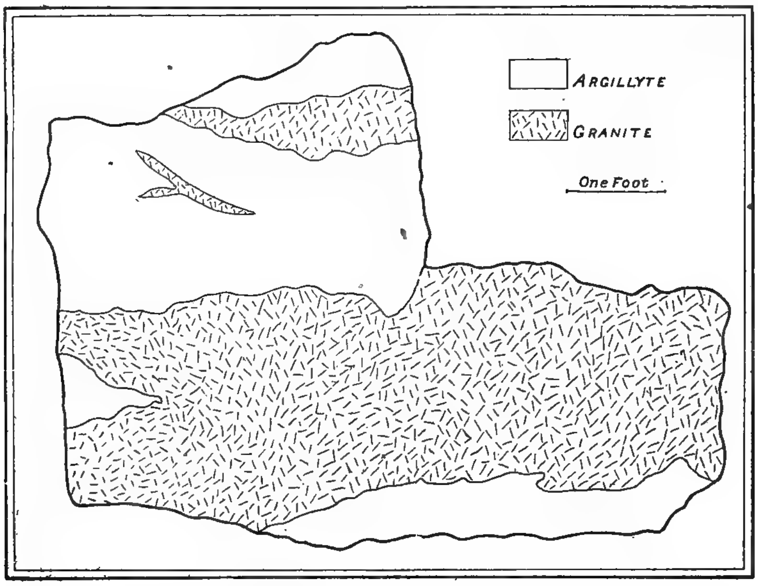


FIG. 78. CONTACT OF GRANITE AND GREENISH ARGILLYTE-LIKE ROCK.
W. ½ S. E. ¼ sec. 1, T. 64-7 W.

Relations of the different parts of the Archean. This subject cannot be discussed fully at this place, as our information on this point is not as complete as might be wished, and the general subject of the structural geology of northeastern Minnesota is to be considered elsewhere. But a few facts and preliminary conclusions, which seem to be the most probable, are here given.

In the first place it may be stated that the granite of the district is separable into two phases,—a granitic and a porphyritic,—which are thought to be closely related as to origin and age, but the latter is at least slightly younger than the former. The granite is eruptive into some of the surrounding rocks. The granitic phase has been seen to cut the green slaty rock in the S. E. ¼ sec. 1, T. 64–7. It also cuts a rock which is regarded as part of the green schist formation on a small island in the N. W. ¼ N. W. ¼ sec. 2, T. 64–7; and some slaty rocks near the east edge of section 1 of the same township. The porphyritic granite cuts the dark argillytes at the small point on the north shore of Kekequabic lake in E. ½ S. W. ¼ sec. 34, T. 65–7. It also seems to be intrusive into the green schists along the north side of the same lake in sec. 31, T. 65–6, and in places it cuts the normal (granitic) facies of the granite. Whether the granite is later than all the other rocks of the Archean is not known, but it seems quite probable that some of them, especially the conglomerate on the south side of Kekequabic lake at its narrowest part, are of later date than the granite. This view seems probable, because (1) The conglomerate is not known to

be cut by the granite—although the former is not known to be unconformable upon the latter; (2) The conglomerate contains pebbles which can be referred to rocks which are older than the granite, and some that may perhaps be referred to the granite itself.

The green schists, the volcanic tuffs, the grits in the N. ½ sec. 6, T. 65–6, and possibly some of the slaty rocks appear to pass conformably into each other. Assuming that there was but one period of volcanic activity in the immediate vicinity of Kekequabic lake, the three rocks above mentioned, which are made up largely or in part of fragmental volcanic material, can be regarded as of the same age. The hornblende porphyryte which exists around the southwest end of Epsilon lake, less than half a mile north of the east end of Kekequabic lake, is thought to represent part of the same magma which furnished the fragmental volcanic material of the rocks just mentioned.

Elsewhere in northeastern Minnesota it has been ascertained that the rocks to which the name Keewatin has been applied are divisible into two unconformable series, the upper of which has developed at its base, at least in places, a marked conglomerate. That this division is possible in the area of the Fraser Lake plate seems probable, and the conglomerate seen on the south shore of Kekequabic lake at its narrowest part may be referred provisionally to the upper division, or Upper Keewatin. Whether other rocks within the area of this plate belong to this division is not determined, but it would seem that the green schists, the tuffs, the grits and some, at least, of the slaty rocks belong to the lower division, or Lower Keewatin. At Kekequabic lake no actual unconformity has been discovered, but it is inferred. However, from the notes and figures presented on pages 450 and 451, of this chapter, we can state that an unconformity exists south of Ogishke Muncie lake in sec. 35, T. 65–6. Here the rocks below the unconformity would be called Lower Keewatin.

In this connection it might be well to consider the possibility of another division of the rocks referred to the Keewatin. The basement on which the Lower Keewatin was laid down has not been recognized in northeastern Minnesota. It is thus probable that another unconformity—*i. e.*, one at the base of the Lower Keewatin—exists in this region. As to what rocks belong below this unconformity we cannot state with certainty, but it would seem that the greenstones of mount Northrop and the Twin peaks may belong below the Lower Keewatin;* at least from our present knowledge of this district it can be stated that these greenstones belong below the Upper Keewatin and appear to be the oldest rocks of the region.

Thus what appears to be the probable, but by no means the demonstrated, succession of the Archean in the Fraser Lake plate may be stated as follows: The oldest rocks are the greenstones of Twin peaks; above these, perhaps unconformably,

*As used elsewhere in this report the Lower Keewatin includes the oldest greenstones, which are supposed to represent the primeval crust of the earth.

come the Lower Keewatin rocks. After the deposition of these rocks came a period of folding and granitic intrusion, and later another unconformable series—the Upper Keewatin—which has also been folded.

*The Animikie.** Within the area of the Fraser Lake plate are a few masses of iron-bearing rock intimately connected with and usually surrounded by the gabbro. This iron-bearing rock is distinctly banded, the bands being from less than a quarter of an inch to several inches in thickness and usually quite sharply defined. The minerals composing the rock are quartz, magnetite, pyroxene, olivine, amphibole and more rarely feldspar. Frequently layers of almost pure magnetite, or of vitreous, coarsely crystallized quartzyte, occur, and many of the layers are composed almost entirely of but two, and sometimes of but one, of the above mentioned minerals. These minerals are usually rather coarsely crystallized, giving the rock a granitic texture, and sometimes the pyroxene or amphibole is in large plates inclosing smaller grains of the other constituents. In places the bands of magnetite are abundant and of several inches or a foot or more in thickness, and the rock forms an iron ore. These rocks are the same in lithological character as the iron-bearing rocks which are developed so characteristically in the next plate to the east (Akeley Lake plate). The areas of these rocks in the Fraser Lake plate are small, and, with the exception of the Gabimichigama lake occurrence, are surrounded at the surface by the gabbro. These iron-bearing rocks are regarded as belonging to the taconyte or iron-bearing member of the Animikie. They may be considered as parts of this formation torn from their original position by, and included in, the gabbro, or as the Animikie still in place projecting through the gabbro mass. The area of these rocks at Gabimichigama lake certainly seems to be in place, resting on the old Keewatin rocks and intruded and overlain by the gabbro.

Four localities are known where these iron-bearing rocks occur in the area of the Fraser Lake plate. These are: (1) Northwest corner of Thomas lake; (2) North side of Fraser lake; (3) Sec. 20, T. 64–6; (4) South side of Gabimichigama lake. Other localities may be found on farther search, especially in the northern half of T. 64–6. At each of the places here mentioned the Animikie rocks are quite coarsely crystallized and are associated with masses of pyroxene and hornblende, which minerals are sometimes in plates an inch or more across. A fine-grained or granulitic gabbro is also sometimes seen near the iron-bearing rock, especially at the Fraser Lake locality.

Thomas lake. Here the iron-bearing rock occurs near the shore in the N. E. ¼ sec. 29, T. 64–7, about half way between the meander corner of the east line of this section and the outlet of the lake. Many fragments of the rock are seen, but only a small amount in place. From the limited amount exposed the dip appears to be about 10° towards the east.

Fraser lake. The Animikie occurs near the shore at the south side of S. E. ¼ S. W. ¼ sec. 14, T. 64–7, and at places a quarter of a mile east of this place. Here is considerable iron ore, some of which is not markedly magnetic and it may be part of the titaniferous ore of the gabbro, but other parts certainly belong with the

*See foot note on page 431.

Animikie. A few years ago some mining for gold was carried on at this place in the iron ore. It is needless to state that the venture was unsuccessful.

Sec. 20, T. 64–6. On a portage, which runs northwest from the most northerly arm of the lake in this section to a small lake in N. ½ N. W. ¼ of the same section, is an outcrop of the iron-bearing rock in the gabbro only a few rods from the small lake. The rock is composed mostly of interbanded quartzyte and magnetite. The strike is approximately east and west, and the dip is 50° towards the south. A section north and south through this place is shown in the accompanying cut (figure 79). The gabbro is of medium grain, is somewhat decayed, and is not interbedded with the other rock, the two being sharply separated. The gabbro holds a few pieces of the iron-bearing rock and does not appear finer-grained at the contact with the main mass of the Animikie. The exposure of iron-bearing rock is less than twenty feet wide, and it extends along the strike for some thirty feet. Just east of the portage trail, and in the strike of this outcrop, is a low ridge where the Animikie rock is exposed for a distance of over 100 feet along the strike, and about thirty feet across the strike. The dip is the same as at the first outcrop. Specimen No. 753G represents the iron-bearing rock from this locality, and No. 754G, the gabbro.

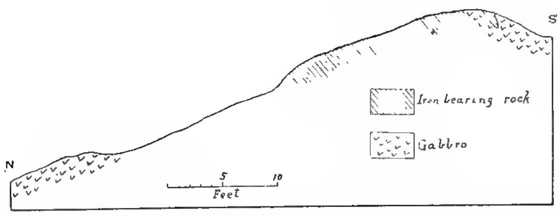


FIG. 79. SECTION NORTH AND SOUTH THROUGH AN OUTCROP OF ANIMIKIE IRON-BEARING ROCK IN SEC. 20, T. 64-6 W.
Vertical and horizontal scale approximately the same.

Gabimichigama lake. The Animikie outcrops over a small area along the south shore of the lake at the east side of sec. 1, T. 64–6, and extends southwest, again coming to the shore in the S. W. ¼ S. E. ¼ of the same section. (For the outline of this area of Animikie, see the sketch map of Gabimichigama lake in the chapter on the Akeley Lake plate.) The iron-bearing rock dips 20° to 60° towards the east, and in places even towards the northeast. It has on its northwest side a part of the underlying Keewatin, entirely recrystallized. The Animikie rocks here occur between the Keewatin and the gabbro in a position similar to that which they occupy a few miles to the eastward.

The Keweenawan. Rocks of the Cabotian division of the Keweenawan occupy practically all the area of the Fraser Lake plate, except a belt about two miles in width along the northern side of the plate. These rocks include gabbro, fine-grained gabbro and granite, the first occupying more than nine-tenths of the Keweenawan area and the two others occurring only in very limited extent. They are all post-Animikie in age and igneous in origin. Moreover, as exposed in this plate, none of them show evidence of having solidified near the surface of the earth, but they are completely crystallized, granitic in structure and evidently solidified at some distance below the surface.

(1). The gabbro. This rock reaches an extensive development in northeastern Minnesota, and, as found in the Fraser Lake plate, possesses essentially the same characters as elsewhere, so a detailed description will not be necessary here. In general, the gabbro is a coarse-grained rock, composed of feldspar (usually near labradorite), pyroxene (diallage), olivine and titaniferous magnetite. The main mass of the rock consists largely of labradorite, with small amounts of pyroxene and less of magnetite, and frequently no olivine. In places, especially in the vicinity of Little Saganaga lake, the gabbro is composed essentially of labradorite and thus forms an anorthosyte. At such places it is coarser grained than customary. At times small

areas of the gabbro or the fine-grained gabbros are found, which are quite rich in titaniferous magnetite. Such an area occurs at Thomas lake, in the S. E. ¼ S. W. ¼ sec. 32, T. 64–7. As has already been mentioned, some of the iron ore on Fraser lake may also be of this character. The grain of the gabbro near the northern edge of its mass is somewhat finer than at a distance from this limit.

The gabbro, as before mentioned, overlies and surrounds, at least at the surface, the Animikie rocks, and it also lies on the Keewatin rocks along the length of its northern border in the area of this plate. When in contact with these older rocks it has profoundly altered them and they are now more or less completely recrystallized. All the Animikie rocks in the area of this plate have been completely recrystallized by the gabbro, and the Keewatin rocks, for a distance of several rods, and sometimes for half a mile from the present surface outcrop of the gabbro, are more or less changed and recrystallized. Good examples of this are seen along the north shore of the lake at the southwest corner of sec. 6, T. 64–6, and also around Gabimichigama lake.*

(2). Fine-grained gabbro. Associated with the main mass of the gabbro, especially in T. 64–7, are small areas of finer-grained or granulitic gabbros to which the name "muscovado" has sometimes been applied in the reports of this survey. These rock are composed essentially of a basic plagioclase feldspar and pyroxene, which is sometimes diallage and sometimes hypersthene. The relations of these rocks to the main gabbro mass are not clearly known within the area of this plate, but are probably the same as to the eastward (Akeley Lake plate), where the fine-grained gabbros are of a somewhat earlier date than the main mass of the gabbro itself.†

Some exposures of these rocks are found as follows: On the north side of the little bay in the centre of the S. E. ¼ N. W. ¼ sec. 27, T. 64–7, Thomas lake, is a bluff forty feet high, of fine-grained gabbro with porphyritic feldspar crystals (No. 270G). South end of small island near southeast corner of S. W. ¼ sec. 32, T. 64–7, Thomas lake (No. 735G). Also on the main shore near the same locality (No. 299W).

(3). Granite. The Keweenawan granites are not well developed in the Fraser Lake plate; in fact they occur only in small amount and then as dikes in the gabbro. Such dikes are seen around lake Polly and especially along the river in the N. ½ sec. 34, T. 63–6, just to the east of that lake. A few miles to the south of this locality, in T. 62–6, the granite appears in large volume, and the dikes above mentioned may be regarded as offshoots from this large granite mass. The dikes are not noticeably finer-grained at the edges than in the centres, indicating that they were intruded while the gabbro was still highly heated.

*See the section on the gabbro contact rocks below, and the sketch map of Gabimichigama lake in the chapter on the Akeley Lake plate.

†See discussion of these rocks in chapter xxiv.

In following up the river just mentioned from lake Polly to a smaller lake in sec. 2, T. 62–6, the usual gabbro of the region is seen in several places. It is quite coarse-grained and is cut by many vein-like forms of red granite. These are of all sizes from half an inch to ten feet in width, and they run in every direction through the gabbro. No. 755G, taken from the west end of the second portage from lake Polly, probably in the S. W. ¼ N. E. ¼ sec. 34, T. 63–6, fairly represents this granite, although it varies considerably in grain, but not so from centre to side of dike. This specimen is a rather fine-grained pinkish granite with glistening black mica scales; under the microscope it is seen to be composed essentially of quartz, orthoclase, biotite and some acid plagioclase. A short distance east of this portage the granite dikes become so numerous that they make up one-third of the rock at any outcrop. Further southeast along this river the dikes are less numerous, but are still occasionally seen in the gabbro all the way to the smaller lake in sec. 2, T. 62–6.

(4). Gabbro contact rocks. In T. 64–7 W. there is shown on the geological map (plate 80) a belt of rocks, between the gabbro on the south and the Archean on the north, which are called gabbro contact rocks. As already stated the gabbro has altered the Archean rocks with which it has come in contact, and in T. 64–6 and the eastern part of T. 64–7, we have been able to separate these altered rocks from the gabbro itself. But in the belt indicated as gabbro contact rocks the field evidence is not complete enough, and the study of the rocks in the laboratory has not progressed far enough to enable us to refer all the rocks of this belt positively to the Archean or to the Keweenawan. These rocks vary considerably in general appearance and grain, but usually are rather fine-grained, dark rocks which possess two features in common. The first is the presence of numerous scales of biotite, and the second is the peculiar yellow, granular appearance of the weathered specimens, which gave rise to the term "muscovado," a term applied to some of these rocks in the earlier reports of this survey, and continued under the form muscovadyte.

The gabbro contact rocks are frequently somewhat schistose, often twisted and broken, and sometimes seem to hold fragments, which, however, are not sharply outlined, of other rocks. Very commonly small, dark veins, composed largely of biotite, cross these rocks. In thin section they are seen to be composed of biotite, feldspar, quartz, pyroxene (frequently orthorhombic) and hornblende. Usually the last two minerals and the biotite occur in large plates, inclosing numerous smaller grains of feldspar or quartz, or of both.

It is probable that future study will show that the gabbro contact rocks may be referred in part to one, and in part to another, of the three following groups: (1) Fine-grained or granulitic gabbros; (2) Fine-grained peripheral facies of the gabbro proper, which facies are quite probably the same as the first; (3) Portions of the underlying Keewatin altered by the gabbro.*

(5). Diabase dikes. Cutting the rocks already described, are a few dikes of diabase, most of which are not more than twenty feet in width. These dikes are of ordinary diabase, and are usually rather fresh. Invariably the sides of the dikes are very much finer-grained than the centres, thus showing that when the

*See remarks on these rocks in chapter xxiv.

dikes were intruded, the surrounding rocks were not highly heated. In general, the dikes fill vertical fissures and strike approximately north and south. In age, the dikes are regarded as Keweenawan. They have all been intruded since the folding of the Keewatin rocks, and two dikes at least are later than the gabbro. The dikes are so uniform in character that it will not be necessary to describe individual occurrences. The locations of the most prominent ones are shown on the map (plate 80).

ECONOMIC RESOURCES.

Merchantable pine exists in many places in the Fraser Lake plate, but large parts of the district are covered by small second-growth timber. Spruce and poplar for pulp in paper-making are common. At present the timber cannot be profitably transported to saw mills, but would be economically important should a railroad reach this district.

In mineral resources iron is the most promising feature, but sufficient amounts of this are not known to warrant mining. It is unlikely that the iron ores of the Animikie in this plate can ever be profitably mined; and the same can be said of what little titaniferous ore is known to occur in the gabbro. It is possible that iron ores will be found in the Keewatin rocks, but none are yet known. A small amount of jaspilyte occurs on the south side, near the east end, of Pickle lake, and jaspilyte pebbles are not uncommon in the Ogishke Muncie conglomerate. The rock from which these pebbles were derived is not known, but probably occurs in the immediate neighborhood of the conglomerates. Nickel ore may also be found in connection with gabbro, but none is known at present.

GEOLOGICAL MAP.

The contour lines were obtained largely from rough sketching from lakes and hills, and the levels of most of the lakes are known from one or more series of barometer readings. The altitudes of a few lakes are known from leveling. Where the contour lines are lacking we know almost nothing of the details of the topography. The outlines of the different rock formations are located fairly correctly in the vicinity of Kekequabic and Gabimichigama lakes. The northern limit of the gabbro in the interior of T. 64–6 is not definitely known. Southwest from Kekequabic lake the geological boundaries are only approximate. No attempt is made to indicate the areas of Keweenawan granite and fine-grained gabbros, but the whole Keweenawan area is mapped as gabbro. Although there are two, and possibly three, unconformable rock series in what is mapped as Keewatin, still our present knowledge will not enable us to indicate, even with approximate correctness, the areas occupied by each series.

ROCK SAMPLES.

The following rock samples have been collected within the area of the Fraser lake plate:

N. H. Winchell's series: Nos. 755-765; 1040-1061B; 1094; 1096; 1098-1106; 1361-1368; 1386-1395; 1400-1427; 1752-1767; 1771.

A. Winchell's series: Nos. 298-308; 313; 349-357; 363B-382.

H. V. Winchell's series: Nos. 66; 458A; 461.

U. S. Grant's series: Nos. 85-97; 245-277; 540-620; 621A-639; 735-755; 764-772; 774; 776-787; 840-846; 850; 853-854A.

CHAPTER XXIV.

THE GEOLOGY OF THE AKELEY LAKE PLATE.*

By U. S. GRANT.

Situation and area. The Akeley Lake plate is situated in the northwestern corner of Cook county and its northeastern corner borders on Canadian territory. On the west is the Fraser Lake plate (No. 80), and on the east the Gunflint Lake plate (No. 82). The Akeley Lake plate includes all of Ts. 64-4, 64-5, 65-4 and 65-5 W. About one and a half square miles at the northeast corner of T. 65-4 W. belong to Ontario. The area of the plate, inclusive of water surface, is then about 142.5 square miles.

SURFACE FEATURES.

Topography. In this plate there are, as in the Fraser Lake plate, two rather distinct types of surface, although here they differ less markedly than in the Fraser Lake plate. The first type of surface is that underlain by the gabbro, practically the southern half of the plate; but here the surface is much rougher than the gabbro surface to the west; in fact in the gabbro area there are some quite marked elevations. The second type of surface is underlain by rocks of Archean age and contains one prominent hill range, the Giant's range. This is a hilly tract, a mile or more in width, which enters this plate on the east at Magnetic lake and runs westward, keeping just to the north of Akeley lake and passing out of the plate just to the north of Gabimichigama lake. In secs. 13 and 14, T. 65-4 W., west of magnetic lake, the highest land is formed of granite; here an altitude of more than 1,950 feet (over 400 feet above Gunflint lake) is reached. To the west and southwest the higher

*The area included in this plate has been examined at various times by different parties of the survey, and a considerable part of the field notes have been published. The individuals who did the work, the dates of the work, and the places of publication are as follows: N. H. WINCHELL, field work of 1878, *Ninth Annual Report*, pp. 83, 84; field work of 1879, *Tenth Annual Report*, pp. 88-90, 98, 99; field work of 1886, *Fifteenth Annual Report*, pp. 372, 378-381; field work of 1887, *Sixteenth Annual Report*, pp. 79-95, 98; field work of 1892, not published; field work of 1893, not published; field work of 1896, *Twenty-fourth Annual Report*. A. WINCHELL, field work of 1886, *Fifteenth Annual Report*, pp. 171, 172; field work of 1887, *Sixteenth Annual Report*, pp. 229-239, 245-247, 268-270, 293-299, 306-315. H. V. WINCHELL, field work of 1888, *Seventeenth Annual Report*, pp. 106-111. U. S. GRANT, field work of 1888, *Seventeenth Annual Report*, pp. 151, 152, 160, 161; field work of 1891, *Twentieth Annual Report*, pp. 83-88; field work of 1892 and 1893, published in part in *Twenty-second Annual Report*, pp. 67, 68, and *Twenty-fourth Annual Report*.

The writer at various times, in 1891, 1892 and 1893, visited practically all (except parts of the N. W. ¼ T. 65-5 W.) of the area of this plate examined by former parties of the survey, and he also examined considerable areas not seen by them. The shores of nearly all the lakes have been examined in detail and in some places the north and south section lines have been followed. In the vicinity of the Animikie iron-bearing rocks, mapping has been done more carefully than elsewhere. Where these rocks outcrop, each section has been crossed, from north to south, at least once and frequently three or more times. In this work, a large amount of data has been collected, but the time allowed for the preparation of this chapter does not permit of a full presentation of the various details. In fact, this chapter is to be considered only as a general preliminary description of the geology of this area, in which area centre several important points in the geology of northeastern Minnesota.

GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA

AKELEY LAKE PLATE

BY U. S. GRANT

Contour Lines

Explanation

Railroads

land passes into the greenstone area, and here (north line of sec. 28, T. 65–4) is the highest point in the plate, 2,038 feet above the sea, as determined by leveling.

To the north of the Giant's range the land slopes northward and in the two northern tiers of sections in this plate the surface is quite flat and featureless. This flat country is underlain by granite and in this respect is similar to the flat gabbro country in the Fraser Lake plate, being a district which is underlain by a massive rock everywhere similar in resistance to destructive forces.

In the eastern part of T. 65–4 is a third type of surface, that conditioned by the Animikie rocks and their sills of diabase. This is a district of marked relief, one of whose hills (centre of sec. 24) rises to an altitude of 1,870 feet, while another (northwest corner of section 26) was found by leveling to be 1,875 feet above the sea. The topography peculiar to the Animikie area is developed characteristically to the east of the district here described in the Gunflint Lake, Rove Lake and Mountain Lake plates, and will be mentioned more in detail in the description of the first of these plates (chapter xxv). This type of topography is not typically developed in the Akeley Lake plate.

The lowest lake level in this area, Red Rock lake, which touches the northern edge of the plate, is about 1,435 feet above sea level. The highest land (2,038 feet) is the greenstone hill already mentioned on the north line of sec. 28, T. 65–4. This makes a difference of over 600 feet between the extremes of elevation in this plate.

Drainage. The Akeley Lake plate lies in the drainage basin of Hudson bay. The southern part of the plate drains northward, and the southern slope of the Giant's range drains southward. The waters from these two sources unite and part is conducted by Cross river into Gunflint lake, and thence, through a depression in the Giant's range at the eastern edge of T. 65–4, to Saganaga lake, which lies just to the north of this plate, The remainder of the drainage south of the Giant's range passes through Gabimichigama lake, thence to Ogishke Muncie and Frog Rock lakes, and through West Sea Gull and Sea Gull lakes to Saganaga lake.

The stream which flows from Gunflint lake to Saganaga lake forms the international boundary. It traverses a region underlain by granite, which, on account of lack of soil, and recent fires, presents a most desolate appearance. The granite bluffs are breaking down under the action of frost, and the forest, where such still exists, seems to spring from the bare rock. Figure 3, of plate MM, shows one of these shattered granite bluffs, and the accompanying forest, and figure 2 of the same plate shows one of the rapids on this stream. Another rapids or falls in this stream is shown in figure 2 of plate PP, in the chapter on the Pigeon Point plate.

The rapids at the outlet of Frog Rock lake, on the second of the lines of drainage, mentioned above, are shown in figure 1 of plate MM.

A feature of interest along the stream connecting Gunflint and Saganaga lakes is the disappearance of this stream, or rather of one branch of it, in a channel filled with boulders, in N. W. ¼ sec. 12, T. 65–4.* (See figure 80.) Here a singular accumulation of boulders is seen (at A, in figures 80 and 81) rising apparently in a cobble stone wall, to a hight of about fifteen feet above the water. This is the appearance as seen in perspective at the distance of about twelve rods toward the south. On approaching nearer, the surface exposed to view is seen to be, not a wall, but a slope of about 20°, and the curious effect is discovered to be simply that of a mass of boulders, filling what is probably an ancient bed of the stream. The boulders are quite uniformly about ten

* A. Winchell. *Sixteenth Annual Report*, pp. 230-232.

inches in diameter. The right and left borders of the boulder-filled bed are abruptly limited by vegetable growths, and a well developed forest surrounds. The farther limit is also sharply determined by a fringe of sedges and a forest covering, as shown in figure 81. Standing water approaches the foot of this slope, but no current whatever sets toward this old channel.

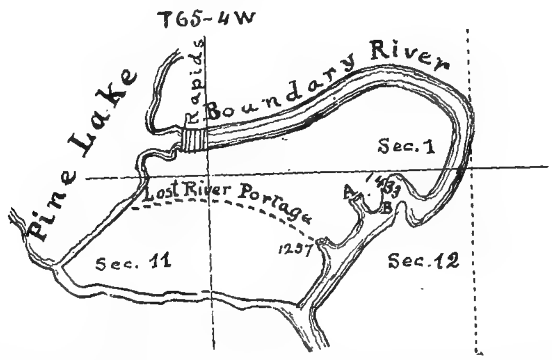


FIG. 80. MAP OF A PORTION OF THE STREAM (BOUNDARY RIVER) CONNECTING GUNFLINT AND SAGANAGA LAKES.

On the contrary, a channel, B., filled with boulders, through which the stream actually flows, goes out toward the northeast. The water here entirely disappears. A view of one of these boulder-filled channels is shown in figure 4 of plate MM.

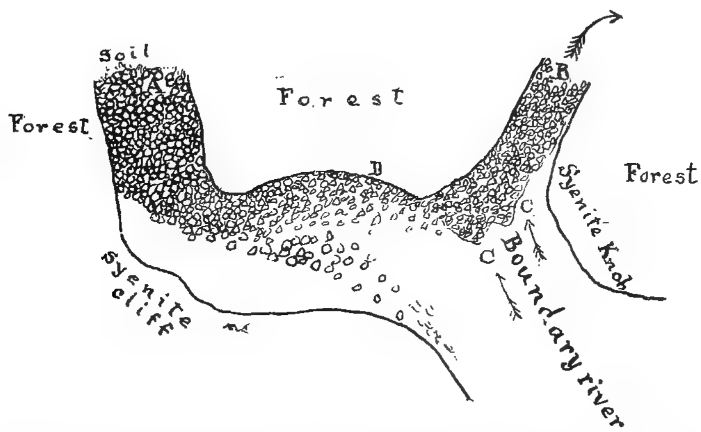


FIG. 81. PART OF THE SAME AS FIGURE 80, BUT ON A LARGER SCALE.

The drift. The drift features of this region have received very little attention, and only a very few general statements concerning glacial deposits can be made. As is usual throughout the northern part of St. Louis, Lake and Cook counties, the glacial drift is quite scanty, frequently almost lacking over considerable areas, and averaging only a few feet in thickness. Rock outcrops are abundant and would be more so, except for the slight covering of post-glacial soil. Foreign boulders are abundant and frequently of great size; coarse hornblende granite, probably from the area of Saganaga granite, forms a large part of these boulders. No morainic deposits have been recognized, although the drift hills in secs. 11 and 12, T. 65–4, east of the south end of Pine lake, may be of this character. There is a drift ridge of considerable size running approximately east and west through the centre of sec. 26, T. 65–4, and in the section to the west a railroad cut has been made in a hill of stratified

drift. A drift hill (or hills) also occurs along the south line of sec. 27, T. 65–4, west of Cross river.

The general direction of ice movement in this district was towards the southwest or rather south-southwest. During the retreat of the ice the northern slope of the land was favorable to the formation of ice-dammed lakes, and, while positive evidence of the existence of such lakes has not been found, it is quite probable that one or more of them, of small area and short duration, existed. In this connection it may be well to mention the marked valley which extends through secs. 15, 22 and 27, T. 65–4, and connects with the valley of Cross river. This valley has a comparatively level floor, and in places the surrounding land rises from 100 to 400 feet above its floor. The exact nature and history of this valley are not known, but it seems probable that it once was a line of drainage.

GEOLOGICAL STRUCTURE.

Brief sketch of the rocks. There are three great divisions of rocks in the area of this plate. The oldest rocks belong to the Archean. They consist of greenstones, granites, conglomerates, graywackes, slates, etc., and they occupy the northern part of the plate. Their southern boundary runs approximately south-southwest from the western edge of Magnetic lake to the northern side of Akeley lake and then westward to the northern part of Gabimichigama lake. The Archean rocks were sharply folded, metamorphosed and much eroded before the next division, the Animikie, was deposited upon them. The Animikie rocks lie along the southern border of the Archean area, and dip off to the south, usually at a small angle. They consist of thinly bedded slaty rocks, the lowermost beds being rich in iron ore, and they contain intrusive sheets or sills of diabase. The Animikie begins in the western part of sec. 34, T. 65–5, and extends eastward, as a very narrow belt between the Archean greenstone on the north and the gabbro on the south, about half way through T. 65–4, where the narrow belt widens out and becomes nearly a mile and a half in width where it leaves the eastern side of the plate. Covering the whole southern half of the plate and overlying the Animikie rocks is the third division. This is of Keweenawan age, and is composed of a vast mass of igneous rock—gabbro.

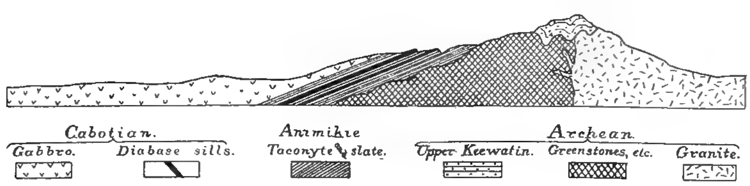


FIG. 82. GENERALIZED NORTH AND SOUTH SECTION THROUGH THE AKELEY LAKE PLATE.

The above sketch (figure 82) shows the general relation of the various rocks in a section drawn north and south through this plate.

The Archean. The rocks included in this division form the northern third of the plate, and they are separated from the overlying later rocks (Animikie and Keweenawan) by a great unconformity. The Archean within this plate is easily separable into two chief divisions—Keewatin rocks and granite; and the former has again been divided in mapping into three parts, the complete relations between which are not fully known. These three parts are the greenstones, unclassified Keewatin and Upper Keewatin.

(1). The Greenstones. On the map is shown a belt of rocks, averaging nearly two miles in width, extending from Frog Rock lake eastward to and beyond the centre of T. 65–4 W., where it disappears under the Animikie strata. The rocks of this belt can be included under the term *greenstone.* They are crystalline rocks, composed essentially of a ferro-magnesian mineral, which is most usually hornblende, and plagioclase feldspar.

These rocks vary exceedingly, even within short distances, in grain and composition, at one time being quite coarse grained and granitic in texture, and again being almost aphanitic. The hornblende varies much in amount and frequently makes up almost the entire rock. In general, these rocks are at present diorytes. At places, especially along the east side of sec. 27, T. 65–5, and in the vicinity of Frog Rock lake, the greenstones contain angular and sub-angular fragments of rock almost like themselves, but nothing like a true conglomerate has been found in the area designated as greenstone. Nor is there any positive evidence of any sedimentary rock within the greenstone area; in fact, this lack of sedimentary rocks and the general lithological character have been the main features used in distinguishing the greenstones from the rest of the Keewatin.

While the original nature of all the rocks of the greenstone area cannot be stated positively, it is certain that the larger part are essentially igneous in origin, although some parts can be regarded as fragmental volcanic rocks. In lithological character some of these recks were certainly diabases and others were of the nature of andesytes, while a large part seem to have been diorytes or possibly gabbros. They have been subjected to much alteration and recrystallization, and it seems likely that parts of them have been altered several times since their original formation as rocks.

Associated with the greenstones, especially in secs. 22, 23 and 24, T. 65–5, are small masses of more acid rocks,—quartz porphyries and quartzless porphyries,—all of which are probably younger than the greenstones. While the evidence for each small mass is not complete, the following facts point to the truth of the above statement as to the age of these rocks. (1) They sometimes occur in the form of small dikes. (2) When in larger masses, they sometimes show a finer grain at the contact lines on the greenstones than at some distance from these lines. Such is the case on the shores of the largest lake in sec. 24, T. 65–5. (3) They have not acquired the schistose structure, which is frequently, though by no means universally, developed in the greenstones. It can be stated here that the greenstones, as a rule, are massive, and cannot be called "greenstone schists," except locally.

As to the age of the greenstones they are regarded as the oldest rocks in the Akeley Lake plate. Their exact age is not known, but there are certain facts which seem to indicate that they form the basement on which the Keewatin rocks were deposited. If this view is the correct one, these greenstones, instead of being of Keewatin age, are really pre-Keewatin and possibly formed part of the original crust of the earth. However this may be, there are certain considerations which ally them in age with the greenstones and greenstone agglomerates found unconformably below the clastic rocks of the Marquette district in Michigan, and which are referred in the nomenclature of the U. S. Geological Survey to the Basement Complex or "Archean,"*

*U. S. Geol. Survey, *Fifteenth Annual Report*, pp. 477–650, 1895.

(2). *The Saganaga granite.* This name has been applied to a large area of granite which exists around and to the south of Saganaga lake. In the Akeley Lake plate the northern fourth of the area mapped is underlain by the Saganaga granite. This rock is a coarse-grained hornblende granite. The coarse-grain, uniform character and the large quartz grains, sometimes over half an inch in diameter, are characteristic features of this granite mass. Exposures of this granite are frequent, and the various exposures differ little from each other. It is seen in characteristic development around West Sea Gull and Sea Gull lakes, and along the boundary water course in the northeast corner of the plate. The massive hills in secs. 13 and 14, T. 65–4, are of this rock.

Along the southern border of the granite in T. 65–5, as it approaches and is in contact with the greenstone, the grain becomes somewhat finer than usual, and the quartz in places is almost entirely gone and the rock becomes a hornblende syenyte. Along this edge of the granite mass its relation to the greenstone can be distinctly seen in many places. Some of the best localities to observe the later age of the granite are: (1) Less than one-fourth of a mile south of the northeast corner of section 23; (2) South shore of West Sea Gull lake in N. W. ¼ N. E. ¼ sec. 17; (3) West of Sea Gull lake in S. E. ¼ sec. 7. At the first of these localities many granite dikes, from one to twenty-five feet in width, are seen cutting the greenstone. At the second locality is a bald bluff of the greenstone which is cut in every direction by branching vein-like forms of granite of the same nature as the main mass of the granite adjoining. These granite dikes show practically no variation in grain from centre to edge. They and the greenstone are cut by a second series of finer grained, more acid granite (aplyte) dikes. At the third locality there are several rounded hills of greenstone, cut in all directions by branching dikes of granite, which are sometimes thirty feet across. The greenstone at this place varies considerably in grain, but is massive. No. 822G is a representative sample of the greenstone at this place. It is a rather fine-grained, hard, dark green rock, composed essentially of hornblende and feldspar, the former in large amounts. The accompanying sketch (figure 83) shows the relations of the greenstone and the granite. The latter is similar to the main mass of the Saganaga granite as exposed at Saganaga lake. But sometimes, near the locality here mentioned, the granite in the dikes becomes some finer grained and poorer in quartz as the distance from the main granite area increases.

FIG. 83. GRANITE DIKES IN GREENSTONE, NEAR CENTRE OF S. E. ¼ SEC. 7, T. 65–5.
The area represented is five feet square,

Near the southwest corner of sec. 15, T. 65–5, and just to the east of this, the greenstone is found cut by granite, by aplyte and by quartz porphyry, all within a distance of a few rods. Each of the cutting rocks seems to be distinct, and the different varieties do not appear to grade into each other, so we assume that the greenstone has been subjected to at least three distinct periods, which, however, may not have been far removed from each other, of acid intrusions. The relation of the quartz porphyry to the granite and the aplyte is not known.

(3). *Unclassified Keewatin.* In the vicinity of Gabimichigama lake and extending northward to Frog Rock lake, is a much folded and complex series of rocks of Keewatin age. These are essentially sedimentary in origin and consist of slates,

graywackes, grits, and in places are conglomeratic. The slate and graywacke phases are well developed north of the western part of Gabimichigama lake and north of the smaller lake just to the west (Agamok lake). A conglomerate exists near the northwestern shore of Gabimichigama lake, in sec. 31, T. 65–5 W., and also at the west side of Frog Rock lake, and about Town Line lake.

The Keewatin rocks included in the area mapped as unclassified Keewatin most probably include strata belonging both to the Upper and to the Lower Keewatin. The district has not been studied enough to enable us to separate these two unconformable parts of the Keewatin, nor to tell exactly what types of rocks belong to each, but it seems very probable that the two parts are composed quite largely of somewhat similar rocks, so that a separation by lithological characters alone is very difficult, if not impossible. We know that the Upper Keewatin includes conglomerates, slates, grits and graywackes, while from the pebbles included in the basal conglomerate of the Upper Keewatin we know that the pre-existing rocks consisted in part of granites, greenstones, jaspilytes, flints and slates.

(4). The Upper Keewatin. Along the western border of the Saganaga granite in the vicinity of West Sea Gull lake a marked conglomerate lies upon the granite. Good examples of this are to be seen in many places, but one of the best localities for the conglomerate is on the rounded point at the centre of the west side of sec. 8, T. 65–5, and just to the west of this place. The actual contact can be seen between the conglomerate and the granite, and large fragments of the latter are included in the former. Near this place the writer formerly described an eruptive contact of the granite on the conglomerate,* but further examination showed that this was incorrect, and that the conglomerate is much younger than and unconformable on the granite.† The conglomerate is composed largely of debris derived from the granite, but also contains foreign material from the adjoining greenstones, and pebbles of jaspilyte and flinty rock. Away from the granite contact the conglomerate becomes finer-grained and varies to a grit, a graywacke, and in places to a slate. The graywacke facies is abundantly developed three miles to the north of this plate at the western bay (in Minnesota) of Saganaga lake.

On the north side of Town Line lake in S. W. $\frac{1}{4}$ N. W. $\frac{1}{4}$ sec. 18, T. 65–5, is a conglomerate (which is probably a part of that just described) holding bands of red jaspilyte.‡

The conglomerate and associated Upper Keewatin rocks have been much folded and now stand usually in highly inclined altitudes with approximately a north and south strike. They dip away from the granite at the contact, but to the west of this line the structure has not been studied.

* *Amer. Geol.* vol. x, p. 8, July, 1892.
† See pages 321 and 322 of this volume; also the description by N. H. WINCHELL, *Twenty-fourth Report*, p. 19.
‡ A. WINCHELL. *Sixteenth Annual Report*, p. 315.

(5). *Résumé of the Archean.* As may be gained from what has already been stated concerning the different parts of the Archean, our knowledge of the relations of the rocks of this age is not complete, but the general Archean history may be stated as follows: The greenstones may be considered the oldest rocks in the area of the Akeley Lake plate; they perhaps belong to the Basement Complex. These rocks are of igneous origin, and have been altered more or less from their original nature, being now mostly diorytes. The Lower Keewatin rocks exist in this area, but their exact boundaries cannot be given, nor can their relations to the greenstones be stated. It is not unlikely that some of the latter rocks are of Lower Keewatin age, for such is the age of a large amount of the greenstones elsewhere in northeastern Minnesota, although, as already stated, the vast mass of these rocks in the Akeley Lake plate are likely to be older than the Lower Keewatin. After the formation of the greenstones, and also perhaps of the Lower Keewatin,* there was an intrusion of granite, the Saganaga granite. After the date of the greenstones, and the Lower Keewatin, these rocks were subjected to a period of folding and elevation, followed by a period of profound erosion. The folding may date from the intrusion of the granite. The erosion was so prolonged that the coarse-grained massive granite was finally brought to the surface through the removal of the overlying rocks. Then came a period of depression, and the sea again covered the greenstones, the Lower Keewatin and the granite. In this sea were deposited the Upper Keewatin rocks, separated from the foregoing by a marked unconformity. After the deposition of the Upper Keewatin, there was another period of folding and elevation, followed by erosion. If we may judge from the scarcity of clastic material in the lower member of the Animikie in Cook county, and from the general straightness of the present northern boundary of the Animikie rocks, it would seem quite likely that this erosion was continued until a peneplain was formed. At any rate, the time interval which must have elapsed between the Upper Keewatin and the Animikie was very long.

(6). *Metamorphism of the Archean.* The alteration of the Archean rocks due to the dynamic forces to which they have been subjected, and to the intrusion of the Saganaga granite, has not been fully studied. It is sufficient to state that some of these rocks have been partially or wholly recrystallized, and that in many of them slaty and schistose structures have been developed. Of a much later date than this metamorphism was that produced by the Keweenawan gabbro. This metamorphism is purely of a contact nature, and does not extend far from the northern limit of the gabbro mass. Along this limit the Archean rocks have been affected, and at the contact entirely recrystallized. The resulting rock varies in mineral composition as did the original rock, but biotite has been quite abundantly developed where the

*See page 322 of this volume.

original rock was less basic, and where more basic, especially near the immediate contact, pyroxene is common.

In many places the rock resulting from this contact metamorphism of the gabbro is a rather fine-grained, granular, rusty-weathering rock to which the name "muscovado" or "muscovadyte"* has been applied. Where less basic this rock weathers quite readily, as at Gabimichigama lake, which lies in a depression along the contact of the Archean and the gabbro. The accompanying sketch (figure 84) shows the distribution of the different formations about the shores of this lake.

FIG. 84. SKETCH OF GABIMICHIGAMA LAKE AT THE CORNERS OF TOWNS 64-5, 64-6, 65-5 AND 65-6.

The Archean rocks (slates, conglomerates, greenstones, etc.) are represented by lines sloping to the right; where dotted, these rocks have been noticeably metamorphosed by the gabbro. The closely lined area is underlain by rocks of the iron-bearing member of the Animikie. The gabbro is indicated by crosses, and diabase dikes by solid black. Scale, one inch to one mile.

The Animikie. The Animikie rocks are the rocks of the Mesabi iron range, and as such are of much interest both geologically and economically. As developed in the Akeley Lake plate these rocks form the eastern end of the Mesabi iron range in Minnesota, and they are the equivalents, both in age and origin, of the Mesabi rocks in St. Louis county. In Lake county the Animikie rocks are exposed only in small isolated areas in, or at the northern edge of, the gabbro, but in sec. 34, T. 65-5 W., they emerge again from beneath the gabbro, and continue eastward to the extreme eastern end of the state. The iron-bearing member, however, passes into Canadian territory completely a short distance to the east of Gunflint lake.

The Animikie can be separated into four divisions on a lithological basis. These divisions are, in ascending order, as follows: (1) The quartzyte member, or the Pokegama quartzyte;† (2) The taconyte or iron-bearing member; (3) The black slate member; and (4) the upper or graywacke slate member. The first and the

*See remarks on these rocks further on in this chapter.
†Often called the Pewabic quartzyte, in the area of this plate.

fourth are not represented in the Akeley Lake plate, but the fourth exists just to the eastward in the Gunflint Lake plate.

(1). The taconyte or iron-bearing member. On the west this member first appears, between the greenstone on the north and the gabbro on the south, near the centre of W. ½ N. W. ¼ sec. 34, T. 65–5. It extends eastward, holding the same position with respect to the adjoining rocks, as a narrow belt for six miles, where it rapidly widens out, and two miles west of the eastern edge of the Akeley Lake plate has a width of a mile and a quarter. The taconyte member lies unconformably upon the greenstone to the north, and in sec. 22, T. 65–4, it completely covers the greenstone and passes over onto the granite on which it rests, also unconformably, to the eastern side of the plate. Contacts with the underlying rock are visible in several places. One of the best is near the centre of S. ½ sec. 21, T. 65–4, where the fine-grained siliceous lower beds of the Animikie can be seen fitting into the irregularities of the old greenstone surface, and in places this Animikie material has settled down into cracks in the greenstone. Another interesting contact is to be observed in a test pit near the west line of sec. 23, T. 65–4.

The dip of the taconyte member west of the centre of sec. 27, T. 65–4, is toward the south, varying from 20° to almost vertical, and the width of the outcrop is from 300 to 1,300 feet. The average dip is about 45°. Where this belt of rocks is the widest, the dip averages about 30°; this would give a thickness of 650 feet, which is probably the maximum thickness reached by these rocks west of the centre of sec. 27, T. 65–4. To the east of this, the dip is much less, and the surface outcrop much wider, being a mile and a quarter in width along the west side of secs. 23 and 24, T. 65–4. An estimate of the maximum thickness of the taconyte member east of section 27 is 900 feet, of which about 75 feet is diabase sills. This estimate is based on an average southerly dip of 10°, and on the assumption that there are no faults or folds which would make the apparent thickness greater than the real. The estimated thickness is possibly too great.

In lithological character the iron-bearing member is similar to this member of the Animikie along the productive portion of the Mesabi iron range in St. Louis county, the chief difference being that in the Akeley Lake plate, magnetite, instead of hematite, is the important iron ore. The term taconyte is applicable to the rocks composing this member of the Animikie. They are composed of jaspery, often spotted, grünerite, siliceous, and cherty schists, or rather slates, usually thin bedded, and frequently containing layers rich in magnetite. The magnetite is especially abundant near the base of the formation.

Breccia. A feature of the taconyte member which deserves mention is a marked breccia, which is seen to good advantage just south of the railroad track in N. W. ¼ S. E. ¼ sec. 24, T. 65–4. It also occurs on top of the high hill just to the north of this locality and also near the southwest corner of the section to the west. The

breccia is composed of angular fragments of Animikie rock, cemented by a fibrous green amphibole. The breccia plane, which is approximately parallel with the bedding of the Animikie, represents a plane of motion, but in which direction the motion occurred is not known. (See the twenty-fourth annual report, page 25.)

Scarcity of quartzyte. One characteristic feature of the taconyte member is that actual fragmental material is largely lacking. In all the slides thus far examined very few show fragmental quartz grains or fragmental grains of other material. The only undoubted fragmental quartzyte yet noticed was found in a traverse across the ridge which separates Magnetic lake from Animikie bay of Gunflint lake in sec. 24, T. 65-4 (No. 1322). But the specimens collected here were not actually *in situ*, although in all probability they were removed only a short distance from their original position. A few other specimens examined also seem to be fragmental quartzytes, but the number of these is very small. There thus is no evidence of the existence of the lower or quartzyte member of the Animikie as a distinct member in the Gunflint Lake region, the taconyte or iron-bearing member being the lowest and resting directly on the underlying Archean, but the taconyte member contains a very small amount of fragmental quartzyte.

Folding. In addition to the general southerly dip of the Animikie there is evidence of gentle folding where the taconyte belt is the widest, while in sec. 21, T. 65-4, there is a pronounced fold. The axes of these folds have a general east and west direction. Some of the smaller folds can be seen near the southwest corner of sec. 22, T. 65-4, and near the north side of N. W. ¼ sec. 26, same township, the Animikie rocks are bent into an anticline where the strata on the south dip 10° towards the south, and on the north 15° towards the north. As exposed, this anticline is about 150 feet across (north and south).

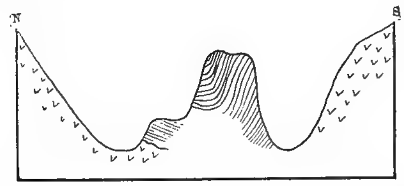


FIG. 85. SECTION SHOWING A SYNCLINAL RIDGE OF MAGNETIC SLATES (IRON-BEARING MEMBER OF THE ANIMIKIE) BETWEEN TWO RIDGES OF GREENSTONE (ARCHEAN).

The section, one-fourth mile long, extends north and south near the east side of S. W. ¼ sec. 21, T. 65-4 W. Vertical scale several times the horizontal. Compare figure 86.

A section made from the north quarter-post of sec. 21, T. 65-4, south for two miles, crossing the pronounced fold mentioned in the last paragraph, is as follows: For a distance of about a third of a mile Saganaga granite; then greenstone cut by this granite. At three-fourths of a mile the iron-bearing slates of the Animikie are seen lying directly on the greenstone and dipping towards the south (see figure 85). A few rods farther the dip of the Animikie changes to the north and soon becomes quite steep. Thus the Animikie strata in the south half of section 21 form a syncline. Before reaching the south quarter-post of this section the greenstone is again seen, and it continues southward for a fourth of a mile from this point, when the Animikie iron-bearing rocks occur dipping towards the south at an angle of perhaps 50° (see section AB in figure 87). After crossing a small thickness of these rocks the gabbro is seen overlying the Animikie, and this igneous rock continues southward to and beyond the south quarter-post of sec. 28, T. 65-4. The Animikie rocks were once continuous, in the form of a anticline, over the greenstone ridge at the north side of section 28, *i. e.*, the southern of the two greenstone ridges mentioned above.*

On going eastward this syncline of Animikie rocks (figure 85) becomes more flat, and a section of the exposures is shown in figure 86.

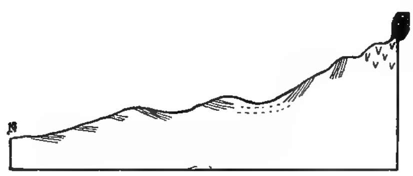


FIG. 86. SECTION NORTH FOR ONE-FOURTH MILE FROM THE SOUTH QUARTER-POST OF SEC. 22, T. 65-4.

Archean greenstone occurs on the south overlain by the Animikie iron-bearing member. This section is about one mile east of that of figure 85.

The Iron-Bearing Rocks at Akeley Lake and Vicinity.

The iron-bearing member of the Animikie, west of the centre of sec. 27, T. 65-4, is different from this member elsewhere in this plate in that it is here composed of highly crystallized rocks. These consist of quartz, magnetite, olivine, hypersthene, augite and amphibole. Frequently the pyroxenes and amphiboles are in large plates inclosing the other minerals. Magnetite is abundant and is usually concentrated into certain layers, and these layers form the iron ore which has been exploited in secs. 28 and 29, T. 65-4. The cause of this crystallized condi-

*Compare section CD on the map accompanying "Sketch of the Geology of the Eastern End of the Mesabi Iron Range in Minnesota." *Engineers' Year Book, University of Minnesota*, pp. 49-62, 1898. This map and section are also used in the *Twenty-fourth Annual Report.*

tion of the Animikie rocks is the contact metamorphism of the great gabbro mass which lies above and just to the south of the Animikie.

These rocks are typically developed in secs. 28 and 29, T. 65-4, and a map of these two sections is here presented (figure 87). These iron-bearing rocks extend east and west in a narrow belt, lying at the base, or on the southern flank, of a marked ridge of greenstone. They contain at least one sill, which is from four to twelve feet in thickness, of a gabbro-like rock—most probably a sill from the great gabbro mass. This sill has been seen in several places, as shown in figure 87, and is best exposed north of Akeley lake. Here the sill is markedly porphyritic with large plagioclases, and is also very noticeably finer grained at its lower and upper surfaces. In addition to this there is, farther south, a larger sill of gabbro (also shown in figure 87) which is also fine grained at its edges, but in its centre cannot be distinguished from the gabbro which occurs so abundantly to the south.

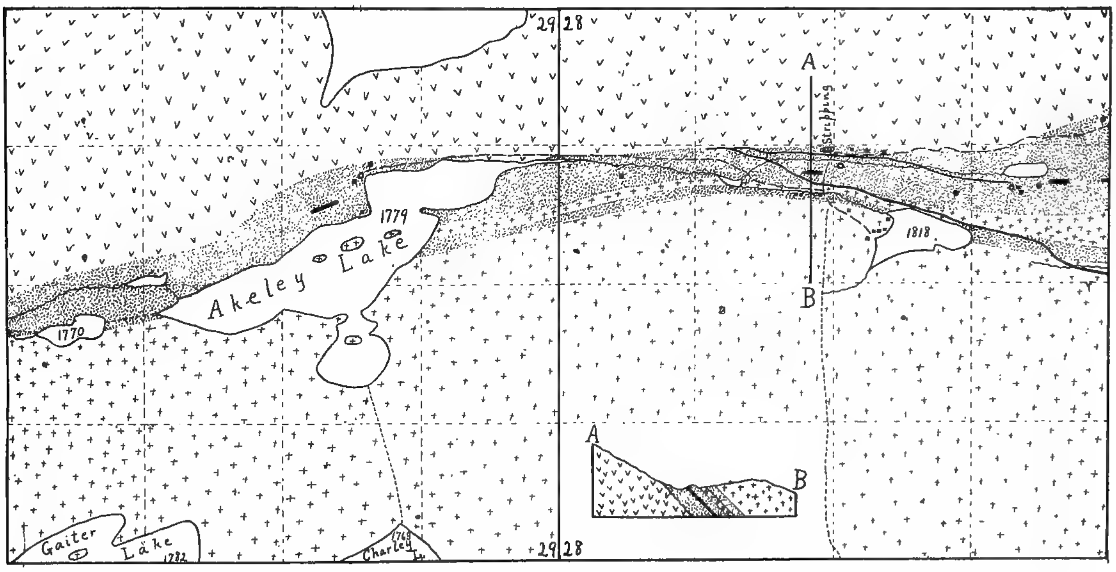


FIG. 87. SKETCH MAP OF SECS. 28 AND 29, T. 65-4 W., SHOWING THE GEOLOGY AND THE WORKINGS OF THE GUNFLINT LAKE IRON CO.

The area covered by the character V represents the greenstone; the stippled area, the iron-bearing rocks (taconyte member of the Animikie); the area covered by crosses, the gabbro (Keweenawan); the solid black, sills of gabbro-like rock. The solid line represents the Port Arthur, Duluth and Western railroad; the broken line of long dashes, wagon roads; the broken line of short dashes, trails. Black squares represent buildings; circles, shafts; solid circles, test pits. Scale, three inches to one mile. Figures in lakes denote altitudes in feet above the sea, as determined by leveling.

The highly crystallized iron-bearing rocks here described have been referred to different ages by different geologists. The state geologist, while formerly referring them to the Animikie, has lately regarded them as of Archean (Lower Keewatin) age, and in this same category he includes the belt of iron-bearing rocks in the S. ½ sec. 21, T. 65-4. In fact, all of the banded iron-bearing rocks in the Akeley Lake plate west of the centres of secs. 22 and 27, T. 65-4, are referred to the Archean. The reasons for this are given in the chapter on Lake county in this volume and in the chapter on structural geology in volume v. On the other hand, the geologists of the United States Geological Survey, especially Messrs. W. S. Bayley and W. N. Merriam, have referred the rocks in question (not including the belt in sec. 21, T. 65-4, which is regarded as of Animikie age) to the gabbro. Mr. Merriam has thus mapped these rocks as part of the gabbro,* and Dr. Bayley, while admitting that possibly part of them may be quartzytes, still includes the vast mass of these rocks in the gabbro.†

The writer believes that these iron-bearing rocks are part of the taconyte or iron-bearing member of the Animikie metamorphosed by the gabbro, and this is the ground also taken by Messrs. H. V. Winchell and A. H. Elftman. The writer has studied these rocks carefully in the field and to some extent under the microscope, but unfortunately he has not had an opportunity to give to them the detailed study that they seem to deserve; so the field notes have not been fully arranged and digested, the microscopic study has only been begun and the chemical investigation has been largely neglected. Nevertheless, there is sufficient known about these rocks to warrant some statements in regard to their age and the cause of their present condition. In these statements the writer, while presenting his own views, hopes that he will exhibit a spirit of fairness and courtesy which should characterize any scientific discussion, the end in view being the presentation of the truth.

The general aspect of these rocks, except in one particular, *i. e.*, their coarsely crystalline nature, allies them with the iron-bearing rocks of the Animikie. They exhibit to a remarkable degree the same minute and coarser bandings, and the same alternations of bands of magnetite and quartz and other materials. They exist in the direct continuation of the strike of the Animike beds, and they are found only in such positions as one would

* *Mon. xix U. S. Geol. Survey*, pl. xxxvii.

† *Nineteenth Annual Report*, pp. 193-210; *Jour. Geol.*, vol. ii, pp. 814-825; vol. iii, pp. 1-20.

with most reason expect to find the Animike, *i. e.*, at or near the northern border of the gabbro. Rocks of this nature exist in a number of places, in such positions, between the two parts of the iron-bearing member of the Animikie, which are by all recognized as of Animikie age, *i. e*,, in eastern St. Louis county and at Gunflint lake. Moreover, what field work has been done makes it clear that these well known parts of the Animikie can be traced by gradual steps into these areas of highly crystalline, banded iron-bearing rocks. This has been stated by Dr. A. H. Elftman for the district south and southwest of Birch lake on the eastern edge of St. Louis county,* and in the Akeley Lake plate these rocks, before disappearing in the swamp in the N. E. ¼ sec. 27, T. 65-4, attain a lower dip, a less crystalline character and a close approach in general lithology to the Animikie (which is called Animikie by all) half a mile distant to the east. And the same characters ally the rocks under discussion to the belt of iron-bearing rocks in S. ½ sec. 21 and S. W. ¼ sec. 22, and these latter rocks have the some lithological characters, and can be traced by frequent outcrops into the well known Animikie just to the east.

These facts are of importance in separating the iron-bearing rocks in question, both from the Keewatin and from the gabbro. In regard to their reference to the Keewatin, it may be said that Prof. N. H. Winchell regarded these rocks as of Animikie age, until he saw rocks of similar lithological nature, south of Disappointment lake, in N. W. ¼ T. 63-8 W., and until certain facts were interpreted to point to a metamorphic origin for the gabbro mass and its associated rocks. In regard to the iron-bearing rocks south of Disappointment lake, the writer can state that he has seen these rocks in company with Prof. Winchell, and saw no conclusive evidence that they belonged to the Keewatin. Their reference to the Animikie seems to do violence to none of the facts observed, but, had not these rocks been known from other localities, where their Animikie age was more certain, the reference of this particular area to the Keewatin would be easy. However, even if these rocks at Disappointment lake belonged to the Keewatin, this fact does not establish the Keewatin age of the Akeley Lake rocks.

One fact of great importance in separating these iron-bearing rocks from the gabbro is the nature of the contained magnetite, which is *non-titaniferous*, while the deposits of magnetite in the gabbro in northeastern Minnesota, are, as far as known, invariably titaniferous. Moreover, even the magnetite, which occurs disseminated in small grains, throughout the mass of the gabbro, seems to be titaniferous.

Attention has already been called to the structural features in regard to the folding of the Animikie rocks in secs. 21 and 28, T. 65-4. Here the simplest explanation of the structure is that the iron-bearing rocks in question in section 28, originally extended in the form of an anticline, over the greenstone ridge to the north, and were continuous with the syncline of Animikie there found.†

Another feature of importance is that, in these iron-bearing rocks in sec. 28, T. 65-4, are some jaspilitic bands. Carbonaceous material is common in the Animikie, especially in the strata immediately overlying the iron-bearing member. And in the gabbro, just to the south of these coarsely crystallized iron-bearing rocks, are fragments, and in one place possibly a mass *in situ*, of rock which can most certainly be referred to the black slate member of the Animikie. That is the member which next overlies the taconyte or iron-bearing horizon, and seems to occur here, just to the south of and above the iron-bearing rocks, where such a member would be expected.

Where the main mass of the gabbro comes in contact with the iron-bearing rocks, it is finer grained, and the two rocks can easily be distinguished, even in the field. In fact, the statement can be made that in the field there was at no time any difficulty in distinguishing the two rocks. The large sill of gabbro in the iron-bearing rocks (see figure 87, on page 473) is like the main mass of the gabbro, and both this sill and the smaller one are of decidedly fine grain at both their upper and their lower sides, thus showing that they are of later date than, and intrusive into, the surrounding rocks. The two sills just mentioned are the only ones known to the writer in secs. 28 and 29, T. 65-4, it being assumed that the different exposures of small sills (as shown in figure 87) all belong to one sill.

It is to be regretted that a careful chemical investigation of the iron-bearing rocks of Akeley lake has not been made in order to show their relationships to those adjoining rocks which all admit to be of Animikie age. In lieu of such chemical examination attention may be called to the mineral composition. In this district the Animikie rocks are not uncommonly somewhat metamorphosed, and now consist of aggregates of quartz and magnetite with certain amphiboles. The crystalline iron-bearing rocks in question consist of aggregates of quartz and magnetite and certain pyroxenes, amphiboles and olivine (often fayalite). Quartz and magnetite, forming bands composed entirely of one or the other of these minerals, or in smaller grains disseminated among the other minerals, are common to both the unquestioned Animikie rocks, and to the iron-bearing rocks of Akeley lake. Thus these two rocks are identical in composition, as far as these two minerals are concerned, the only difference being that in the latter rocks these minerals (quartz and magnetite) are usually in larger grains. The other minerals may be tabulated as follows:

Unquestioned Animikie—	Akeley Lake Rocks—
Actinolite,	Olivine,
Grünerite,	Fayalite,
Cummingtonite,	Hypersthene,
Green hornblende.	Augite,
	Green hornblende.

*See especially plate vi, of the *Twenty-second Annual Report*.
†Page 472, and figures 85 and 86, and section AB, in figure 87.

The minerals actinolite, grünerite and cummingtonite have not always been carefully distinguished. They are undoubtedly all present in the partially metamorphosed Animikie, but the grünerite and cummingtonite are the most common. These two minerals (or perhaps only one of them) occur in the highly crystallized iron-bearing rocks in question, but usually not in any abundance. It is evident that the actinolite and green hornblende in the undoubted Animikie rocks could furnish the elements necessary for the augite and green hornblende in the highly crystallized iron-bearing rocks under discussion. Moreover, the grünerite ($FeSiO_3$) and the cummingtonite ($[MgFe]SiO_3$) of the Animikie could furnish the elements necessary for the formation of the fayalite (Fe_2SiO_4), the olivine ($[MgFe_2]SiO_4$) and the hypersthene ($[FeMg]SiO_3$). It is thus seen that the material necessary for the formation of the highly crystallized iron-bearing rocks can all be obtained from the Animikie rocks, and thus the fact that the former rocks contain gabbro minerals can be explained without assuming that these rocks are part of the gabbro. It is not the intention of the writer to affirm that there has been no transfer, during the metamorphism of these rocks, of material from the gabbro. This may have taken place, but it is not to any great extent necessary, for the Animikie contained the material needed to form these minerals.

Another important difference between the Akeley Lake rocks and the gabbro is that the latter contains much feldspar, while in the former this mineral is in very small quantities or lacking entirely. And it may be repeated that there was observed in the field no gradation between the gabbro and the iron-bearing rock, the two being distinct and easily separable. Moreover, the sills of gabbro already mentioned show by their fine-grained edges that these rocks were intruded by the gabbro, and these sills are also sharply separated from the inclosing rock.

Dr. Bayley admits the possibility of some of the quartzose bands in the Akeley Lake rocks being metamorphosed quartzytes, but the bands composed of gabbro minerals, which bands often contain quartz, he regards as parts of the gabbro. The writer, on the other hand, regards not only the quartzyte bands, but also the bands of magnetite and of other minerals as strata of the iron-bearing member of the Animikie profoundly metamorphosed by the gabbro. It seems certain that all of the rocks mapped as iron-bearing rocks in figure 87, page 475, are of one and the same origin and age. Indeed, to the writer, it is evident that nearly all of the non-feldspathic peripheral phases of the gabbro described by Dr. Bayley,* excepting the titaniferous magnetites, are metamorphosed Animikie strata, and even some of his granulitic gabbros are here included.†

The writer has presented above the facts which seem to him to practically demonstrate the Animikie age of the rocks in question. It may be added that the gabbro is known to have markedly metamorphosed and entirely recrystallized other rocks with which it came in contact, so the metamorphism of these iron-bearing rocks is nothing unusual, although it may be that certain features of these basic, but at the same time quartzose, rocks—such as their position or their chemical composition—aided in making this metamorphism so pronounced.

(2). The black slate member. This overlies conformably the taconyte member and is rather sharply separated from it lithologically. No contacts between the two members have been seen, but as far as the outcrops examined are concerned there seems to be no difficulty in separating the two members.

The black slate member consists essentially of fine-grained, black, siliceous, apparently carbonaceous slates which are frequently quite fissile, although the fissile character is not well developed in the few exposures which are seen in the Akeley Lake plate. In thin section some of the typical parts of this member (rocks Nos. 908G, 961G, 961aG, 961bG) are seen to be composed of numerous small angular fragments of quartz in a cement of dark color and apparently carbonaceous nature. These black slates are well developed along the bluff on the south side of Cross river near its mouth, in S. $\frac{1}{2}$ S. E. $\frac{1}{4}$ sec. 24, T. 65–4. Here the river flows over the upper surface of a diabase sill, under which, and about a quarter of a mile to the north of the river, appear the slates of the taconyte member of the Animikie. On the south side of the river, and forming the first sixty feet of the bluff, are some black to gray, sometimes flinty, slates, which are as distinct from the iron-bearing slates below as from the black carbonaceous slates above. This belt of slates is not exposed elsewhere, and it is here included with the black slate member, although it

* *Jour. Geol.*, vol. ii, pp. 816–825.
† *Jour. Geol.*, vol. iii, p. 18, Nos. 944 and 947.

might perhaps be included with the taconyte member. Above these slates, and in sharp contact with them, is a belt of the typical black slates, but here, instead of being slaty, the rock appears quite massive, is lacking in lamination, and in the field might be taken for igneous rock. The part of this rock which is exposed in the bluff, and just to the south of the bluff here, shows a thickness of at least a hundred feet.

Another typical exposure of the massive phase of these black slates occurs in the hill just south of the railroad in the N. E. $\frac{1}{4}$ N. E. $\frac{1}{4}$ sec. 26, T. 65–4. West of this there are almost no exposures of this black slate member; in fact it is not extensively exposed anywhere in this plate except at the two localities already mentioned.

(3). The diabase sills. The Animikie strata have been intruded by vast sheets of diabase which follow approximately the planes of bedding of the intruded rocks, although sometimes cutting across them. Two extensive sills and several smaller ones have been noted in this plate. The most pronounced is that which occurs just north of the mouth of Cross river and extends westward for over two miles. These sills are of diabase and are quite constant in petrographical character. They will be spoken of more fully in the description of the Gunflint Lake plate (chapter xxv).

The Keweenawan. The rocks of the Cabotian division of the Keweenawan overlie and are younger than the Animikie. They are composed of igneous rocks, and are easily separated into four groups—gabbro, fine-grained gabbro, granite and diabase dikes.

(1). The gabbro. The southern line of the Animikie is the northern line of the gabbro from the eastern edge of the plate westward as far as the Animikie rocks are exposed. On the east the gabbro is in contact with the black slate member of the Animikie; farther west it cuts across this and comes upon the taconyte member, and finally, in the western part of sec. 34, T. 65–5, it cuts entirely across this member and lies upon the Archean.

Contacts of the gabbro with the underlying rocks are rather common, and in each this vast mass of igneous rock is seen to have a marked effect upon the underlying rocks, completely recrystallizing them for at least a distance of several rods from the contact, and for a much farther distance, inducing the crystallization of certain new minerals in them. The effect of the gabbro upon the narrow belt of Animikie iron-bearing rocks in the vicinity of Akeley lake has already been mentioned. The effect on the greenstones is less marked, for they were already completely crystalline before the gabbro affected them. Still, near the gabbro contact, pyroxene, which is almost never found elsewhere in the greenstones, begins to develop, and close to the gabbro the hornblende has largely disappeared or taken the form of large plates, inclosing smaller grains of the other minerals of the rock.

Pyroxene is abundant, either in large grains or in much smaller ones with rounded outlines.

Where the gabbro has come in contact with the sedimentary rocks of the Archean, it has altered them profoundly. This can be seen especially well about the shores of Gabimichigama lake.* The first effect of the gabbro is the development of minute flakes of biotite all through the rock; then the biotite flakes become larger and the quartz loses its clastic appearance, and finally the rock becomes entirely recrystallized into a mica schist or gneiss, composed of quartz, feldspar, biotite and frequently hornblende, and even pyroxene (sometimes orthorhombic) very near to the gabbro. These altered Archean clastics frequently possess a yellow, brown-sugar-like appearance, and have accordingly been termed "muscovado" in some of the reports of the survey.

The gabbro varies, as in the Fraser Lake plate, and to the westward, considerably in the relative abundance of the different minerals. The normal phase in this plate is an olivine gabbro. In the vicinity of Little Saganaga lake, the ferro-magnesian minerals become scarce or practically entirely lacking, and the rock is composed of labradorite, making an anorthosyte.

(2). Fine-grained gabbro or granulitic gabbro. Associated with the gabbro mass, especially along its northern border, is a considerable quantity of rock of the same mineral composition as the gabbro proper, but of much finer grain. These fine-grained gabbros are very abundant in places, but it is impracticable to map them separately from the main gabbro mass without considerable detailed field work. In the vicinity of Muscovado lake, and about the most northern projection of Bashitanaqueb lake, the fine-grained gabbros occur in typical development (No. 857G). Here, especially at the latter locality, they show a pronounced separation into layers from two inches to a foot or more in thickness. There is no apparent difference between the various layers, and they are separated simply by a crack, which becomes more noticeable as the rock weathers. The appearance of these layers is shown in figures 5 and 6 of plate MM. The layers dip towards the south at a small angle, usually about 10.°

REMARKS ON FINE-GRAINED GABBRO, GRANULITIC GABBRO AND "MUSCOVADO."

In the writer's field notes† rocks called fine-grained gabbros or granulitic gabbros are mentioned many times. These rocks are commonly confined to near the northern edge of the great gabbro mass, and they have peculiar characters which render them easily recognized in the field and under the microscope. These rocks are of fine, but nearly uniform grain, probably the average size of the constituent mineral grains being only about one-fifth the size of the grains of the usual gabbro with which the fine-grained gabbros (granulitic gabbros) are intimately associated. On weathering, these fine-grained rocks become yellow or brown and crumble into fine sand. When fresh they are commonly gray, light or dark in color. Under the microscope they are seen to have a granular texture, being composed of allotriomorphic, approximately equidimensional grains, which frequently have rounded outlines. The constituent minerals are basic plagioclase, augite (diallage), olivine, magnetite (titaniferous), hypersthene, biotite and hornblende. Usually only two or three of these minerals are

*See figure 84, page 470.

† *Twenty-fourth Annual Report.*

present in large amounts in a given section. Thus these rocks vary and may be called, according to the mineral composition, gabbros, olivine gabbros, hypersthene gabbros, norytes, etc.

While these granulitic gabbros are mapped as part of the great gabbro mass of northeastern Minnesota, and while they are regarded as the same in origin as the main coarse-grained gabbro, still they are of a little earlier date than the main gabbro mass and are regarded as representing some of the first consolidations from this gabbro magma. Fragments of all sizes of this granulitic gabbro are included in the coarse-grained gabbro, which latter cuts the former in many dikes and stringers. As a rule the two rocks are sharply marked off from each other at their contacts, and near the contacts neither rock appears different from what it does away from the contacts. At a few of these contacts gradations between the two rocks are seen, but the passage from one rock to the other is complete in a distance of an inch or two. It can be stated as a general fact that areas of any size of intermediate rock do not exist where the granulitic gabbros are typically developed; but at and to the west of Poplar lake, where the typical granulitic gabbros are almost or quite lacking, there are stages of the gabbro which may be called intermediate between the usual gabbro and the fine-grained (granulitic) gabbros. The areas of granulitic gabbro are scattered through the coarse gabbro near its northern border, and these areas vary in size from a few square feet to many acres. They are especially abundant at and south of the south-eastern corner of T. 65-5, in the vicinity of Muscovado lake, and just to the north of Bashitanaqueb lake.

In the various reports of this survey, the term "muscovado" (or "muscovadyte") has been applied to these granulitic gabbros, but these rocks are not to be confounded with rocks of a different nature to which the term "muscovado" has also been applied. That rocks, of at least two origins, had been included under this name was first pointed out by Mr. H. V. Winchell.*

Dr. W. S. Bayley, in 1892, stated that the "muscovados" were granulitic phases of the gabbro,† and later, he described in detail the petrographical characters of these granulitic gabbros.‡ However, while the main mass of the rocks thus described by Dr. Bayley undoubtedly belong to the granulitic gabbros, it is evident that he included under this designation a few rocks of an entirely different nature, *i. e.*, those belonging to the second class of "muscovados" to be mentioned shortly. For instance, rocks Nos. 1334 and 1335,§ which he designates as granitic gabbros, are, according to the writer's interpretation, parts of the Archean greenstone metamorphosed by the gabbro¶ while Nos. 944 and 947,‖ stated to have narrow seams of granulitic gabbro, are parts of the iron-bearing member of the Animikie metamorphosed by the gabbro.

It was at the writer's suggestion that the preliminary examination of the "muscovadytes" reported in the twenty-first annual report° was undertaken, and as a result of this examination and of private discussion of the question, Prof. N. H. Winchell stated as probable the dual nature of the rocks included under this term,** at the same time stating the possibility, or probability, of the granulitic gabbros being a product of the profound metamorphic action of the great gabbro mass upon the Archean greenstones. He has elsewhere†† given his reasons for now considering both classes of "muscovadytes" as of one origin, and for regarding them, not as Archean rocks metamorphosed by the gabbro, but as steps of lesser or greater metamorphism of these Archean greenstones, the final product of which metamorphism was the production of the great gabbro mass itself.

The writer in a preliminary report has called attention to these fine-grained or granulitic gabbros.‡‡

As has already been stated, one class of rocks to which the term "muscovado" has been applied includes the granulitic gabbros mentioned above. The other class of rocks are of Keewatin (in some cases of Animikie) age. In this latter class are both sediments and greenstones, their present peculiar nature being due to the metamorphosing action of the gabbro magma. These rocks are thus found without (north of) the northern limit of the gabbro, while the granulitic gabbros are found within (south of) this limit. The metamorphism of this second class of "muscovadytes" of course increases as the actual gabbro contact is approached. The easily recognizable metamorphism extends for several rods, and in cases for a quarter of a mile or more, from the present surface exposure of the gabbro. In this metamorphism the fragmental character of the original rock is lost, and it becomes a holo-crystalline, almost granitic aggregate of several minerals, chief among which are quartz, feldspar, biotite, hornblende and magnetite. Biotite is almost always developed in this process,§§ and the original bedding of the rock is sometimes preserved. On weathering, these rocks frequently take on a crumbling, rusty, yellow or brown appearance, very similar to weathered forms of the granulitic gabbros. As the original composition of these older rocks varied, so does the mineral composition of the recrystallized forms. Pyroxene is rarely seen except in the immediate vicinity of the gabbro, and here sometimes grains of pyroxene, both augite (diallage) and hypersthene occur, perhaps products of exomorphic metamorphism. Still there is usually no practical difficulty in distinguishing these metamorphosed rather acid sediments from the main coarse gabbros, and also from the granulitic gabbros. Where the older rocks become more basic and approach or become greenstones, the rock resulting from this metamorphic action bears more of a resemblance to the

* *Seventeenth Annual Report*, p. 130.
† *Nineteenth Annual Report*, p. 201.
‡ *Jour. Geol.* vol. iii, pp. 1-20.
§ *Nineteenth Annual Report*, pp. 195, 196. 201.
¶ No. 1335 has been figured in *Nineteenth Annual Report*, p. 196; and in *Jour. Geol.*, vol. iii, p. 6.
‖ *Jour. Geol.*, vol. iii, p. 18.
° Pages 143-152.
** *Twenty-first Annual Report*, p. 152.
†† Chapter on Lake county in this volume, and chapter on structural geology in vol. v.
‡‡ *Twenty-second Annual Report*, p. 77.
§§ See page 469.

granulitic gabbros. In these basic phases of the recrystallized Archean rocks hornblende is abundant, and augite and hypersthene occur at times near the gabbro contact. Not infrequently one of these basic minerals is developed in plates which hold more or less rounded grains of the other minerals of the rock. The resemblance to the granulitic gabbros is greater where the original Archean rock was of somewhat similar original composition to the former. But in present composition, except where strongly acted on by the gabbro, these rocks are hornblendic rather than pyroxenic. Such basic Archean rocks exist just to the north of the belt of ferruginous quartzyte in T. 65-5.*

Types of the first class of rocks called "muscovadytes," *i. e.*, the granulitic gabbros, exist, as mentioned above, around Muscovado lake and north of Bashitanaqueb lake. Nos. 735G, 857G and 857aG are typical specimens of these rocks. The second class of these rocks, *i. e.*, metamorphosed Keewatin rocks, are seen in good development at Gabimichigama lake† and along the south shore of Disappointment lake.

From study in the field and in the laboratory the writer has become convinced of the existence of these two classes of rocks termed "muscovadytes"—classes of different origin and nature—and he thinks it possible, by a judicious combination of study in the field and in the laboratory, to escape from confusing one class with the other.

(3). Granite. As in the Fraser Lake plate, the gabbro is cut by a few dikes of red granite. Such occur at the north end of Ida Belle lake in the S. E. ¼ sec. 35, T. 64-4; on the south shore near the east end of East and West lake; on a point near the centre of the west side of sec. 7, T. 64-4, Big Round lake; along the south shore of Little Saganaga lake in secs. 16 (especially the east half) and 17, T. 64-5; on an island in Gabimichigama lake in N. W. ¼ N. E. ¼ sec. 6, T. 64-5. Some small masses of this granite also occur in the gabbro; they are all probably of later date than the gabbro. Such are found on the west side of the portage south from Akeley lake; a short distance north and east of the southwest corner of sec. 16, T. 64-4, and also a short distance west of this same section corner.

(4). Diabase dikes. Cutting the gabbro and all the earlier rocks are a few diabase dikes. These are always exceedingly fine grained at the edges and coarser in the centres.

One of these dikes, which runs east and west through the granite of West Sea Gull lake south of the centre of sec. 5, T. 65-5, is peculiar in that it bears olivine, which has the same ophitic relation to the feldspars as does the augite. This rock is No. 662G. The exact age of these dikes is not known. Some of them, at least, are later than the gabbro. One such dike is seen cutting the gabbro on Cross river near the north side of sec. 34, T. 65-4, and another was found in the gabbro at the east end of Big Round lake in E. ½ S. W. ¼ sec. 8, T. 64-4, while still another occurs at Kakigo (or Black Trout) lake in N. E. ¼ S. E. ¼ sec. 34, T. 65-5.

ECONOMIC RESOURCES.

A considerable quantity of merchantable pine exists in the Akeley Lake plate. There is also a good supply of spruce and poplar. Nickel ore has been reported from several places in the gabbro, but the survey has not had an opportunity to investigate these reports. It is not impossible that deposits of nickel ore will be found, as the gabbro sometimes bears traces of this mineral.

Iron ore. As has been stated in the description of the Animikie rocks, the taconyte member contains large quantities of iron ore in the form of magnetite. This is more concentrated toward the base of the formation, where there are sometimes layers of almost pure magnetite several inches or a foot or two in thickness.

*See figure 87, page 473.
†See figure 84, page 470.

Quite a number of test pits have been sunk into these iron-bearing strata and in sec. 28, T. 65-4, mining was begun in 1892 and 1893. The Port Arthur, Duluth and Western railroad was completed to this place, and the Gunflint Lake Iron company did considerable work in this section in the years mentioned, but the shipping of ore was not begun. This company put down several test pits in secs. 28 and 29, T. 65-4, and also two shafts. One of these, at the north side of Akeley lake, is seventy-five feet deep. The other, in the S. E. ¼ N. E. ¼ sec. 28, is eight by twelve feet in size and is 105 feet deep. This shaft passed through the usual rocks of the taconyte member of the Animikie at this place, and in its lower part found considerable iron ore. However, this ore was not found in sufficient quantity for profitable mining without hand sampling, and the project was abandoned late in the summer of 1893. With a higher price for iron ore than is now paid, and with careful working, it is probable that ore could be mined here at a profit, especially if the ore could be smelted on lake Superior.

The ore is in general a low grade bessemer ore with no titanium, but there are layers of high grade ore also. Several chemical analyses of the ore are as follows:

Metallic iron,	58.40	54.01	63.98	62.05
Silica,	8.22	9.37	8.90	7.14
Phosphorus,	.036	.032	.028	.113
Manganese,	4.92	5.02	None.	......
Alumina,	.52	.07	......	......
Titanium,	None.	None.	Trace.	......

In sections 22, 23 and 24, T. 65-4, some exploratory work has been done, and as far as the work has gone it shows that the rocks contain about as much ore as in sections 28 and 29. An analysis from the ore in N. W. ¼ N. W. ¼ sec. 23 gave: Metallic iron, 55.60; silica, 10.02; phosphorus, .042; manganese, 4.34; alumina, .34; titanium, none.

GEOLOGICAL MAP.

The boundary separating the greenstone and the unclassified Keewatin from each other is only approximately located. Otherwise the formation boundary lines are considered to be correctly located. More detailed work will probably show only small and unimportant changes in these boundary lines. The contour lines in the immediate vicinity of the iron-bearing rocks are approximately correct, and the hights of many of the lakes were obtained by leveling.

ROCK SAMPLES.

The following rock samples were collected within the area of this plate:

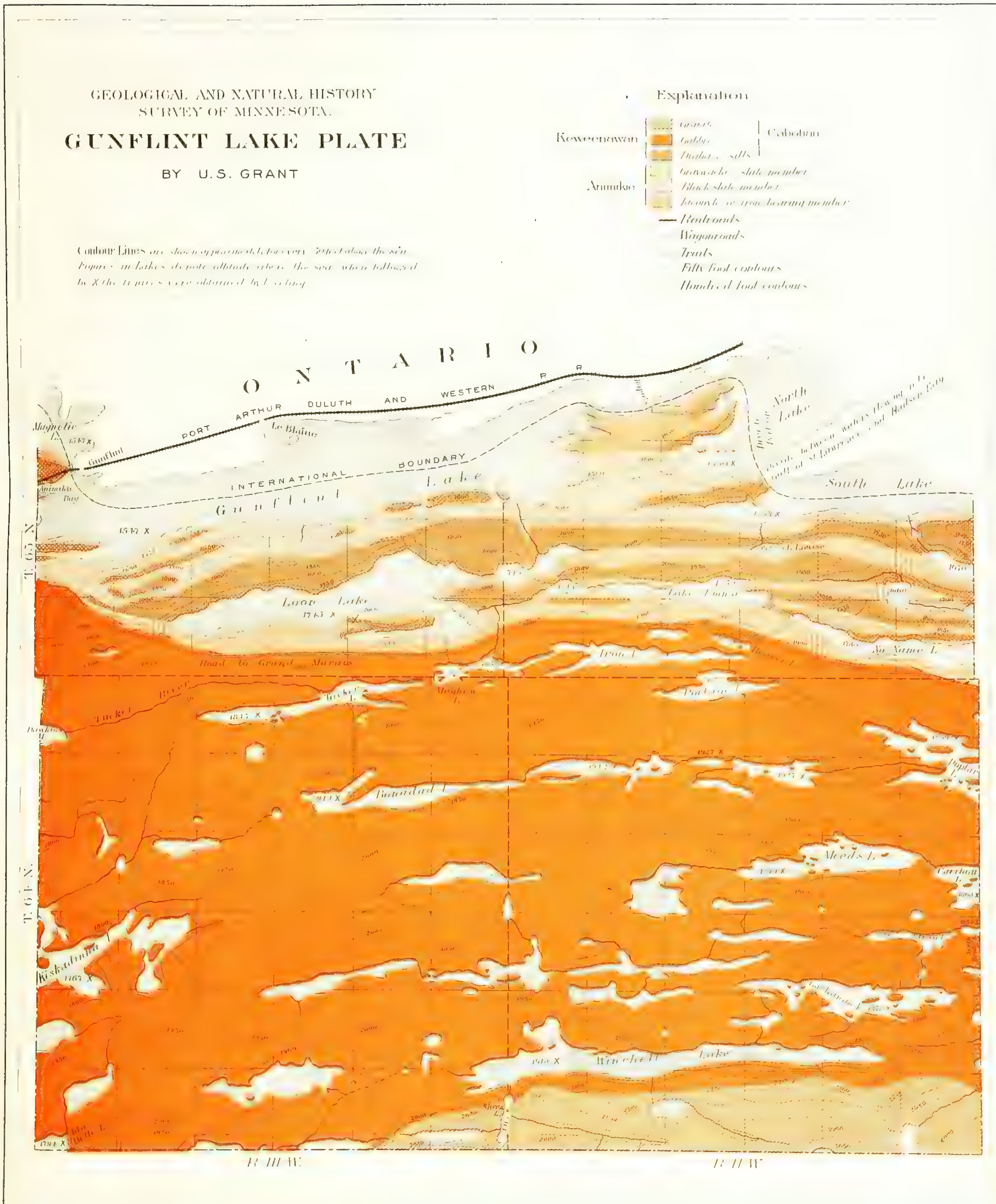
N. H. Winchell's series: Nos. 313-315; 730-737; 767-773; 1071, 1072; 1088-1092; 1318-1365; 1379-1384; 1772-1785; 1891-1897; 2047-2050; 2052, 2053.

A. Winchell's series: Nos. 358; 578-607; 647-656; 660-673; 822-834; 843-886.

H. V. Winchell's series: Nos. 446-458; 459, 460.

U. S. Grant's series: Nos. 6, 7; 43-45; 61-65; 232-244; 645-675; 821-839; 846-849; 851, 852; 855-893; 896-909; 929-950A; 953-961C; 963-966; 968-969E.

A. H. Elftman's series: Nos. 449-526; 556-558.


GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.
GUNFLINT LAKE PLATE
BY U.S. GRANT
Explanation
Keweenawan
Animikie
Cabotian
Railroads
Wagonroads
Trails
Fifty foot contours
Hundred foot contours
ONTARIO
PORT ARTHUR DULUTH AND WESTERN R R
INTERNATIONAL BOUNDARY
Gunflint Lake
North Lake
South Lake
Magnetic L.
Loon Lake
Road to Grand Marais
Iron L.
Tucker L.
Poplar L.
Gaskin L.
Kiskadinna
Winchell Lake
Meeds L.
No Name L.
T. 65 N.
T. 64 N.
R. III W.
R. II W.

CHAPTER XXV.

THE GEOLOGY OF THE GUNFLINT LAKE PLATE.*

By U. S. GRANT.

Situation and area. The Gunflint Lake plate is situated on the northern edge of Cook county, and borders on Canadian territory. On the west is the Akeley Lake plate (No. 81), and on the east the Rose Lake plate (No. 83). The Gunflint Lake plate includes Ts. 64–2, 64–3, 65–2 and 65–3, west of the fourth principal meridian, but the last two townships are not complete, running into Canadian territory. The plate, inclusive of water surface, contains, approximately, 105 square miles.

SURFACE FEATURES.

Topography. In this plate there are three distinct types of topography, a southern, a central and a northern. The southern and the northern are not developed in the two plates to the west (Akeley Lake and Fraser Lake plates), except that the northern begins in the eastern part of the Akeley Lake plate.

The southern type of surface is rugged and almost mountainous. It consists of ridges, known as the Misquah† hills, which lie along the south side of Winchell lake at the southern edge of T. 64–2. The Misquah hills form the highest land in Minnesota, and within the area of this plate are the highest and the third highest points known in the state. The highest point is the hill top at the east side of sec. 35, T. 64–2. This is 2,230 feet above sea level.‡ The third highest point is the hill in the northern half of section 34, of the same township, which is 2,213 feet above

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*The area included in this plate has been examined in part, at various times, by different parties of the survey, and a considerable part of the field notes has been published. The individuals who did the work, the dates of the work and the places of publication are as follows: N. H. WINCHELL, field work of 1878, *Ninth Annual Report*, pp. 80–83; field work of 1879, *Tenth Annual Report*, pp. 79–88; field work of 1887, *Sixteenth Annual Report*, pp. 65–79; field work of 1896, *Twenty-fourth Annual Report.* A. WINCHELL, field work of 1887, *Sixteenth Annual Report*, pp. 233–274. H. V. WINCHELL, field work of 1888, *Seventeenth Annual Report*, pp. 104–106. U. S. GRANT, field work of 1888, *Seventeenth Annual Report*, pp. 152–159, 169–176; field work of 1893, *Twenty-fourth Annual Report.*

The writer, in 1893, examined a considerable part of the area of this plate described previously by others in the annual reports of the survey. The examination of Ts. 65–2 and 65–3 was conducted in more detail than the rest of the plate. In these townships the shores of practically all the lakes were examined and many of the north and south section lines were followed, and in places the topography was relied upon for the location of geological boundaries. In Ts. 64–2 and 64–3 no detailed examinations were conducted and large parts of these townships were not visited. A considerable amount of information has been collected concerning the Canadian shores of Gunflint lake, but is not included in this chapter. The time allowed for the preparation of this chapter will not permit of detailed descriptions; hence only a general preliminary account of the geological features of the district is given, but it is expected that future work will not alter the main points presented.

† The Chippewa word for red. The rock of the hills is red granite.

‡ The hight was not absolutely determined by leveling, but from the hill in the northern half of sec. 34, T. 64–2 (which by level is known to be 2,213 feet above the sea), this highest point was determined to be higher, and it was closely estimated to be 2,230 feet.

the sea. The Misquah hills are a conspicuous feature of the district, not only on account of their hight but also because of the marked red color due to the "red rocks" or Keweenawan granites which compose them. This redness is very marked in places, especially where the hills have been overrun by fires, exposing bare rock over considerable area.

The central type of surface is the comparatively level plateau underlain by the gabbro. This level country has already been spoken of in the description of the Fraser Lake plate (chapter xxiii), and need not be discussed here. It is in marked contrast with the hilly region to the south which rises higher than this plateau, and also with the hilly region to the north which, however, where it joins with the plateau, is of about the same altitude as the plateau, but towards the north becomes lower.

The northern type of surface is distinctly characteristic of the region underlain by Animikie rocks in Cook county. It consists of long, parallel ridges running approximately east and west, with sharp mural escarpments on the north sides of the ridges and on the south gentle slopes. Between the ridges and running parallel with them are long lakes.

A generalized section from north to south through this northern region is as follows: First a long, narrow lake; on the south side of the lake a steep talus slope, beyond which is a vertical cliff composed of slates dipping southward at a small angle. The top of the cliff is composed of a sill of diabase which has been intruded between beds of Animikie slate. Beyond the top of the cliff the land rises gradually for a short distance until coming almost to the top of the diabase sill. Then begins a long, gentle slope southward about on the upper surface of the sill. This slope, however, does not extend far enough to bring one to the level of the northern foot of the ridge. Beyond the gentle slope comes another lake, considerably higher than the former, and on the south side of this the talus, the cliff and the gentle southward slope are again repeated.

As an example of how the general land surface and the lake levels rise toward the south, in the northern part of this plate, we may cite Gunflint lake which is 1,547 feet above sea level, while less than a mile to the south is Loon lake, nearly 200 feet higher, and less than half a mile south of the latter is Mayhew lake, over a hundred feet above Loon lake.

One of the best examples of the northward facing escarpments peculiar to the Animikie area is mount Reunion on the south shore of Rove lake (to the east of the Gunflint Lake plate), as shown in figure 3 of plate NN. Here is the lake, the talus slope and the cliff, all in marked development. The lower half of this cliff at mount Reunion is of slate, and the upper half is a diabase sill.* Another similar

*No. 2064.

FIG. 1. VIEW LOOKING NORTHWEST ACROSS THE WEST END OF GUNFLINT LAKE. GRANITE RANGE IN THE DISTANCE. (p. 483.)

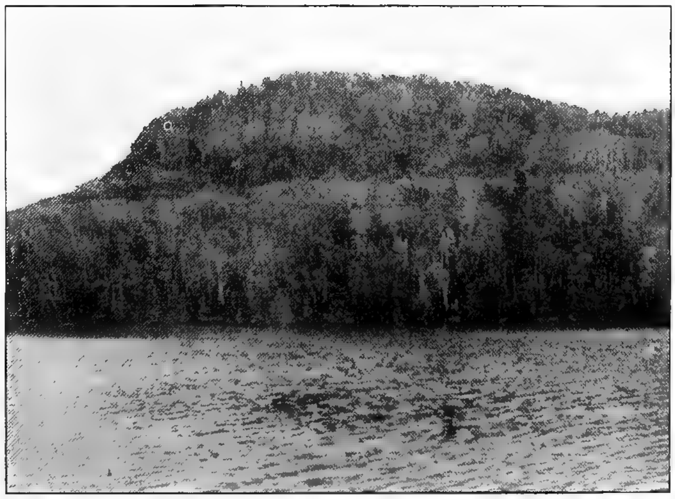


FIG. 2. ROSE LAKE MOUNTAIN, SOUTH SIDE OF ROSE LAKE, FROM THE NORTH. SIMILAR IN STRUCTURE TO FIGURE 3. (pp. 483, 492.)

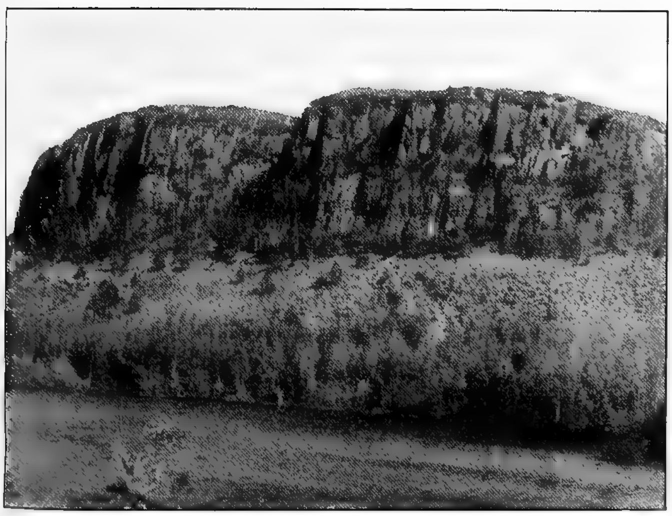


FIG. 3. MOUNT REUNION, SOUTH SIDE OF ROVE LAKE, FROM THE NORTH. THE LOWER HALF OF THE CLIFF IS OF ANIMIKIE SLATES AND THE UPPER HALF IS A DIABASE SILL. (No. 2064.) (pp. 482, 492.)

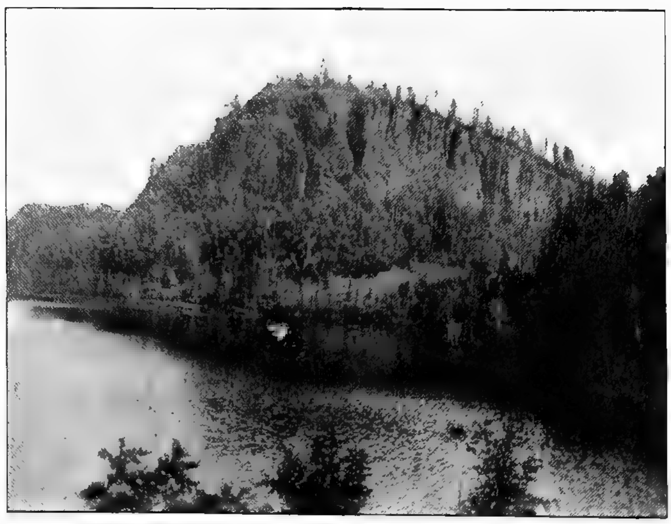


FIG. 4. SOUTHWARD DIPPING RIDGE OF ANIMIKIE SLATE, CAPPED BY A DIABASE SILL, VIEWED FROM THE WEST. EAST SIDE, NEAR SOUTH END OF SOUTH FOWL LAKE. (pp. 483, 496.)

cliff is Rose Lake mountain, shown in figure 2 of plate NN, while figure 4 of the same plate shows a north and south section through one of these ridges. This is at the east side, near the south end of South Fowl lake.

The numerous lakes, elongated in an east and west direction, of the Animikie area, as well as the numerous northward facing cliffs, suggest the probability of a series of comparatively recent east and west fault lines along the north sides of which the strata were depressed. The same elongation of the lakes is to be noticed in the gabbro area to the south, especially in T. 64–2, but here there is no high land or cliff on the south side of each lake. (While these lakes may, in part at least, owe their existence to dams of glacial deposits, still the east and west troughs in which they lie are not due to drift deposits, but are troughs in the bed rock.) As will be stated in the paragraphs devoted to the Animikie, the evidence for profound faulting in these strata, aside from the evidence of topography, is small. It seems that the present surface configuration could have been brought about by erosion acting on gently inclined strata of different degrees of resistance, the thin bedded and fissile Animikie slates being much more susceptible to disintegration and erosion than the diabase sills. And even the gabbro has an indistinct sheeted structure dipping off at a low angle toward the south (figures 5 and 6, plate MM).

To the north of this plate, *i. e.*, along the north shore of Gunflint lake in Canadian territory, the rugged Archean type of topography, as already mentioned in the description of the Fraser Lake and Akeley Lake plates, is well developed; and the Giant's range, here composed of granite, runs eastward from the north end of Magnetic lake.

A view, looking northwestward from the high diabase crowned ridge (Prospect mount) at the south side of sec. 29, T. 65–3, is presented in figure 1 of plate NN. The large body of water is Gunflint lake; the point in the foreground is the point on the south side of the lake in sec. 30, T. 65–3; the narrow channel of water in the centre is the constriction between Gunflint and Magnetic lakes; the small point to the right and in front of the constriction is the point on the south side of Animikie bay; the water beyond the constriction is Magnetic lake; the low hills beyond Gunflint lake are southward-sloping Animikie ridges, while in the distance are the granite ridges of the Giant's range, the highest land in view.

The lowest water in this area is that of Gunflint and Magnetic lakes, 1,547 feet above sea level, and the highest hill, south of the east end of Winchell lake, is 2,230 feet above the sea, making a difference between the extremes of elevation of 685 feet.

Drainage. The area of the Gunflint Lake plate lies in two great continental drainage basins, that of Hudson bay and that of the gulf of St. Lawrence. The divide

on the international boundary line between these two systems of drainage is the portage connecting North and South lakes. The former is 1,550 feet above sea level, and the latter 1,558 feet, and along the portage a hight of 1,600 feet is not reached. In the Hudson bay basin North, Emma, Portage, Mayhew and Loon lakes flow into Gunflint lake, while Tucker lake and the bodies of water in the western part of T. 64–3 empty into Cross river (see Akeley Lake plate), which finds its way into Gunflint lake. The waters of this lake flow northward to Saganaga lake and then westward to Lake of the Woods. In the St. Lawrence basin the waters of South lake and some of the smaller lakes immediately adjacent find their way through the Arrow and Pigeon rivers into lake Superior, while the lakes in T. 64–2 and the eastern part of T. 64–3 empty into lake Superior through the Brulé river.

The drift. Very little is known concerning the glacial deposits of this plate In general it may be stated that the drift is comparatively thin or almost lacking; this is especially the case in the northern third of the plate, more so than in the southern two-thirds. Weathered rock is not common and was evidently removed by glacial action. The direction of the last glacial movement, as recorded by striæ, was approximately towards the south, thus differing from the movement to the west in Lake and St. Louis counties, which was toward the south-southwest or southwest. It is to be noted that this direction of movement was directly at right angles with the long axes of the lakes. No terminal moraines have been recognized, although it is not intended by this to state that none exist. There are some drift hills west of Loon lake.

GEOLOGICAL STRUCTURE.

Brief sketch of the rocks. As in the Akeley Lake plate we have three distinct systems of rocks: the Archean, the Animikie and the Keweenawan. The first is confined entirely to Canadian territory, except, possibly, a small area of granite on the south side of Magnetic lake at the extreme western side of the plate, and will not be discussed. North of Gunflint lake are slates, semi-crystalline and crystalline schists and granite. The schistose rocks have a general east and west strike and high dip. Lying on the eroded edges of those schists, and also in places on the granite, are the Animikie rocks dipping at a low angle to the south. Above these and to the south is the vast mass of the gabbro. The geological structure is thus essentially the same as in the plate to the west (Akeley Lake).

The Animikie. This plate contains the most easterly of the iron-bearing rocks of the Mesabi iron range in Minnesota, and is therefore of considerable interest. The three members of the Animikie exposed here are the taconyte or iron-bearing, the black slate and the graywacke slate members. These three divisions are all well exposed, and it was in this district that it was found possible to separate the Ani-

mikie strata into the three members just mentioned. They are quite distinct from each other in lithological characters, and, because of this, large east and west faults, which have been supposed to exist, in order to account for the peculiar topography of the Animikie district, would be easily recognized. As a matter of fact, there is no evidence yet found in the sequence of strata which would indicate east and west faults of a throw of many feet. The thin bands of magnetite and the peculiar spotted taconyte of the lower member have not been found to the south of the upper limit of this member; and the same can be said of the dense black, sometimes massive, rocks of the black slate member. If either of these rocks occurred to the south of their normal position, as would be the case if there were east and west faults with a down throw on the northern side sufficient to cause the high cliffs, these rocks would be readily recognized on account of their marked petrographical peculiarities.

One of the best places to see the complete sequence of strata in the vicinity of one of the supposed fault scarps is on Cross river, in the S. E. ¼ sec. 24, T. 65-4, just west of the limits of the Gunflint Lake plate. Here there is a continuous exposure from the magnetic slates of the taconyte member through one of the sills and up into the black slate member. This locality was visited in 1896 by Messrs. N. H. Winchell, H. F. Bain, A. H. Elftman and the writer, and all agreed that, at least at this cliff, there was no vertical fault. The question of the existence of north and south faults in this district has not been investigated carefully, but, as far as now known, the evidence for such is comparatively slight.

The Animikie rocks have a general south to south-southeast dip, which varies from 5° to 30° or even steeper. The large majority of the exposures show a dip of from 6° to 12°, and the average has been estimated at about 10°, or possibly less. The high dips are found at the southern edge of the Animikie area where these strata disappear under the gabbro. Almost invariably the southern exposures of the Animikie within a few rods of the gabbro contact show a dip of not less than 15°. While this gentle southward dip is characteristic of the whole formation, there are some minor irregularities, especially near the base of the formation, showing a gentle folding by a force acting in a north and south direction, and there are also indications of pressure at right angles to this direction. The lower part of the taconyte member north of Gunflint lake is sometimes considerably contorted, and in places brecciated. A breccia plane has already been mentioned under the description of the taconyte member in the Akeley Lake plate, and another small horizontal plane of brecciation has been noted in the black slate member at the eastern edge of the Gunflint Lake plate and about an eighth of a mile south of South lake (No. 1000G).

The thickness of the different parts of the Animikie in the Gunflint Lake and Akeley Lake plates is not definitely known, but the following estimates have been

made of the maximum thickness of each member, assuming an average dip of 10°, and the absence of faults and folds which would make the apparent thickness greater than the real.

Maximum thickness of the Animikie in feet.

	Sediments.	Diabase.	Total.
Graywacke slate member,	1,650	250	1,900
Black slate member,	950	100	1,050
Taconyte or iron-bearing member,	825	75	900
Quartzyte (Pokegama) member lacking,	.....	.....	.....
Total,	3,425	425	3,850

(1). Taconyte or iron-bearing member. The rocks of this member of the Animikie are essentially the same as in the eastern part of the Akeley Lake plate, but towards the east, especially between North and Gunflint lakes, banded jaspers are not uncommon. In this same vicinity are found some peculiar, spotted, green rocks (Nos. 1276 and 1005G), which seem to contain some of the original glauconite which has been considered as the original source of the iron ore of the Mesabi range.* Another peculiar type of rock is one which is most commonly seen in pebbles and fragments on the beaches. It is blood red in color and is very hard (No. 1004G). On inspection the rock is found to be composed of bright red, rounded grains, smaller than an ordinary pin's head, imbedded in a darker matrix. Under the microscope the red grains are seen to be hematite with some fine-grained quartz, and the matrix is composed entirely of this fine-grained quartz which is so common to the taconytes and jaspilytes.

On the north shore of Gunflint lake a peculiar part of the taconyte member is a rough conglomerate, or more likely a breccia, of flint fragments cemented by limestone (Nos. 312, 1310, 1311 and 815W). Near the east end of this lake and on the north side the base of the Animikie is somewhat conglomeratic (Nos. 812W and 436H), but in thin section many of the apparent pebbles which are even a quarter of an inch in diameter are seen to be concretionary in structure, being composed of concentric rings of limonite and fine-grained quartz. The matrix is of the usual fine-grained quartz of the taconyte.

(2). Black slate member. Comparatively few outcrops of this member occur in this plate, but some are seen near the south shores of Gunflint and South lakes.

These exposures are of very fissile, black, carbonaceous slates. In one place, on the northern slope of Prospect mount, which is the high hill near the southern edge of sec. 29, T. 65-3, some small white or colorless crystals occur in this black slate; they have not yet been fully studied (Nos. 970G, 972G, 973G).†

* J. E. Spurr. *Bulletin x.*

† Under date of May 2, 1898, Prof. N. H. Winchell writes from Paris, concerning these rocks, as follows:

"No. 970G. The nearly isotropic substance is kaolinic—a result of decomposition of cordierite or of andalusite, probably the former.

"No. 972G. Similar to No. 970G, but coarser and showing some muscovite as a part of the alteration product.

"No. 973G. This is similar, but still coarser. The forms (and some of the original material) of the andalusite are still visible. This slide indicates andalusite rather than cordierite, but neither can be affirmed. Some fresh specimens of this slate might show good crystals and characters of cordierite or of andalusite.

"Prof. A. Lacroix, who made the above notes on these slides, says he has seen in his collections from the Pyrenees identically the same transformations of his slates, subsequently altered to kaolinite, but in his case the intrusive rock is granite."

As stated in the description of the Akeley Lake plate the black slate member can readily be separated from the taconyte member near the mouth of Cross river. The massive part of the black slate member which occurs here is not seen in the Gunflint Lake plate, as it lies largely below the waters of Gunflint lake, and at the east end of this lake where this part probably exists is low ground with no exposures. Between this member and the graywacke slate member above there is not such a sudden transition as at the base of the black slate member. A convenient line of separation between the two upper members is the large diabase sill lying between Gunflint and Loon lakes and extending eastward just south of South lake.

(3). Graywacke slate member. This member is composed of black to gray slates and fine graywackes, with some flinty slates. The upper part shows coarser detrital matter, and the highest beds seen are fine-grained quartzytes and quartz slates. The strata of this member are well exposed along the south side of Loon lake and especially on the north side of the long point (sec. 35, T. 65-3) on the south side of this lake. Towards the west end of the lake some fine-grained quartzytes occur.

(4). Diabase sills. Associated with all members of the Animikie are extensive sheets of diabase which have been intruded between the Animikie strata, and which are now exposed over considerable distances. As has been stated in the discussion of the topographic features of this plate, the sills, called the Logan sills,* cap the precipitous hills of the region and form a large part of the rock exposed on the gentle southern slopes of these hills. In this way the sills, as far as surface exposure goes, make up a large part—in places over a third—of the Animikie, but the actual thickness of these sills is nowhere near a third of the thickness of the Animikie. The sills were intruded along planes of weakness in the Animikie strata, *i. e.*, mainly between the different beds. They are not always continuous over long distances, although frequently several miles in length. The most pronounced of these sills is that which caps the highest ground between Gunflint and Loon lakes and extends eastward close to the south shore of South lake. This sill is nearly if not quite 100 feet in thickness. A section through this and an adjoining sill is shown in the accompanying illustration (figure 88):

All of the diabasic rock in the Animikie within the area of this plate is regarded as intrusive, and no evidence of cotemporary volcanic activity is known.†

An important point in regard to these diabase sills is their relation to the gabbro. It may be said at once that we do not have positive knowledge that the gabbro and the sills are of the same date and are the same rock, the sills being simply offshoots from the main gabbro mass. The two rocks are in general of the same chemical and mineralogical composition; they are both later than the Animikie; they occur in close proximity to each other. The writer is inclined to separate the diabase sills from the gabbro, but admits that this separation is not yet proven. In this connection, it will be well to make some statements concerning the differences between the sills and the gabbro, but it must be borne in mind that these statements are made without an opportunity for careful and thorough microscopical and chemical investigations. The differences here stated are those which exist in

*Cf. A. C. LAWSON. *Bulletin viii.*
†A. C. LAWSON. *Bulletin viii*, p. 48.

the locality where the two rocks come most closely together, *i. e.*, in the vicinity of Gunflint and Loon lakes, and it is here that we would expect likeness rather than differences, if the two rocks were the same. The similarity of the two igneous rocks, at a considerable distance from each other, when they differ near together, is not good evidence of their sameness and actual continuity.

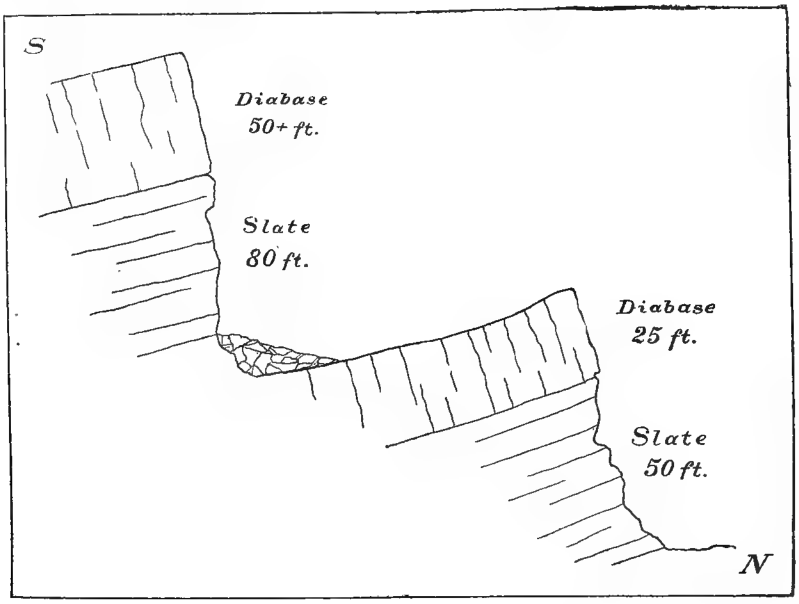


FIG. 88. SECTION NORTH AND SOUTH THROUGH THE NORTH PART OF PROSPECT MOUNTAIN.
S. W. ¼ sec. 29, T. 65-3 W.

1. The sills are considerably altered, *i. e.*, the pyroxene has usually largely been replaced by secondary minerals, while the gabbro is usually fresh and the olivine as well as the pyroxene is usually unaltered.

2. The sills are essentially non-olivinitic; at least traces of olivine, even when altered, are not common. The gabbro is normally olivinitic.

3. The sills are quite rich in ferro-magnesian minerals, giving a dark gray or black color to the rock. The gabbro is usually rich in feldspar and rather poor in ferro-magnesian minerals, and the rock is light gray in color. When a basic mineral predominates, it is mostly iron ore, which is not the case with the sills.

4. The sills are in structure ophitic; the gabbro is granitic. This holds true also of the coarsest grained sills, and of the finest grained gabbro. In this connection, it might be well to mention some sills in the Animikie at Akeley lake in the Akeley Lake plate; these are apparently of gabbro. They are fine grained at their edges, but even here the structure is more nearly that of the gabbro, and not that of the ordinary sills.

5. The sills are very fine grained, almost glassy at the lower and upper sides, even in the thickest sills. The gabbro is not very fine grained at the contact with the Animikie rocks, and even on the edges of the apparent gabbro sills mentioned above, the fineness of grain nowhere approaches that of the edges of the ordinary sills.

6. The sills, even the largest ones, have macroscopically altered the Animikie rocks for only a very few feet, or even inches, from the contacts, while the metamorphism of the Animikie at the gabbro contact is profound, extending for a distance of several rods.

7. The gabbro and sills have not been traced together; neither have they been found in contact. In the map the sills have not been shown in contact with the gabbro; this is on account of lack of exposures. They may, of course, come into actual contact with the gabbro.

8. Where the sills and the gabbro come nearest together the two rocks are easily distinguished, even in the field. The few specimens about which there is question have been, as far as examined microscopically, easily referred to one or the other.

If we assume that the sills are of a different age from the gabbro, we then have little evidence in the area of this plate as to their relative age. They have been referred to as post-Keweenawan in age, or possibly as late as the Silurian.* The writer, while not being able to make any positive statement regarding the age of these sills, still is inclined to the idea that they are of earlier date than the gabbro.

The Keweenawan. As in the Akeley Lake plate the rocks of the Cabotian division of the Keweenawan are separable into the usual gabbro, granite and fine-grained gabbros, the last not being developed in such large amount as in the Akeley Lake

* A. C. LAWSON. *Bulletin viii*, p. 47.

plate. The Keweenawan rocks cover all of Ts. 64-2 and 64-3 and extend half a mile or more beyond the north limits of these townships.

(1). The gabbro. The gabbro mass underlies nearly all the Keweenawan area of the plate; the only exception being a narrow belt of granite along the southern side of the plate. It is the usual gabbro and need not be described in detail. In some places, especially about Poplar lake and the series of lakes in secs. 7, 8, 9 and 10, T. 64-2, and secs. 10, 11 and 12, T. 64-3, there are numerous exposures where the gabbro is considerably finer grained than is usual, but still not as fine as the fine-grained gabbros seen elsewhere. This variety of the gabbro (represented by Nos. 989G, 990G and 991G) in places does not seem to be sharply marked off from the ordinary type of coarse gabbro, but elsewhere the two facies are seen in sharp contrast. A few yards east of the south end of the portage, which runs from Tucker lake to the long lake a mile south of Tucker lake, and back a little from the water (S. W. ¼ N. W. ¼ sec. 11, T. 64-3), the two facies of the gabbro are seen intimately interbanded. The bands are very sharply separated from each other, and the coarser gabbro (No. 989aG) seems to have intruded the finer (No. 989G). The accompanying sketch shows this interbanding, which dips to the south about 15°.

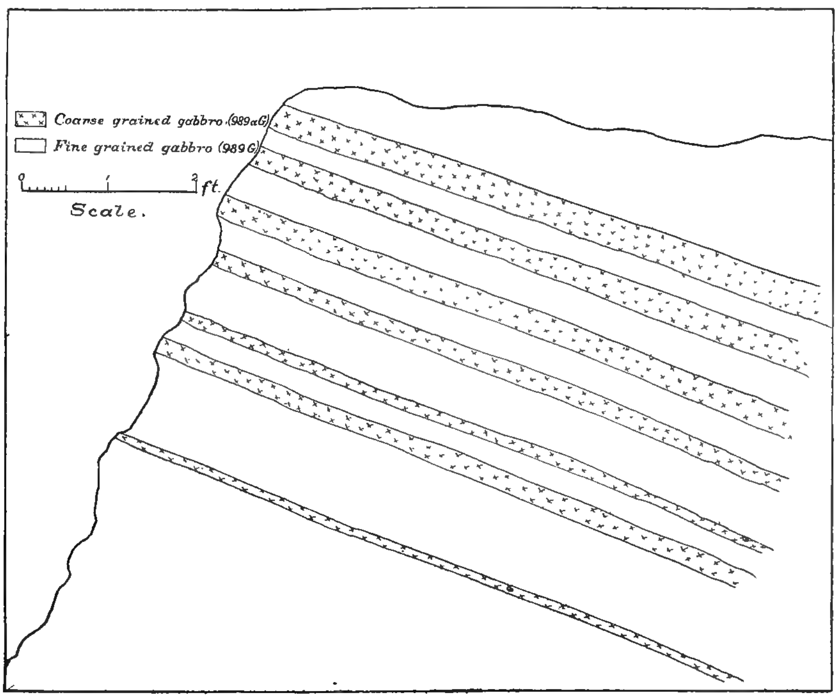


FIG. 89. INTERBANDING OF FINE AND COARSE-GRAINED GABBRO.
S. W. ¼ N. W. ¼ sec. 11, T. 64-3 W.

In the vicinity of Iron and Mayhew lakes, the gabbro is highly charged with magnetite, and becomes in places an iron ore. The ore, however, is highly titaniferous, and there is a large quantity of it to be seen. Two analyses of this iron ore

from Iron lake show, respectively, 58.48 and 52.46 per cent of metallic iron, and 12.09 and 2.23 of titanium binoxide.

ECONOMIC RESOURCES.

Aside from the timber, iron ore is the principal object of economic interest in the area of this plate. Near the bottom of the Animikie on the north side of Gunflint lake, and between this lake and North lake, magnetic iron ore occurs in many places. No large and economically important deposits have yet been found, but the future may show that such exist. Considerable hematite and limonite have been reported from Canadian territory near the east end of Gunflint lake. Considerable deposits of titaniferous magnetite occur in the gabbro at Iron and Mayhew lakes, and elsewhere.

Nickel ore of considerable richness has been reported from several places in this plate, but the survey has had no opportunity to examine the reported finds. Nickel occurs in small quantity in parts of the gabbro, especially in the olivine, and it is not improbable that in certain places the nickel is concentrated sufficiently to furnish a good ore. In this connection, it may be said that no well authenticated report of nickel ore of sufficient richness and extent for profitable mining has yet been presented. It is understood that the first reports of the finding of rich nickel ore were from the N. W. ¼ sec. 25, and N. E. ¼ sec. 26, T. 64–2.

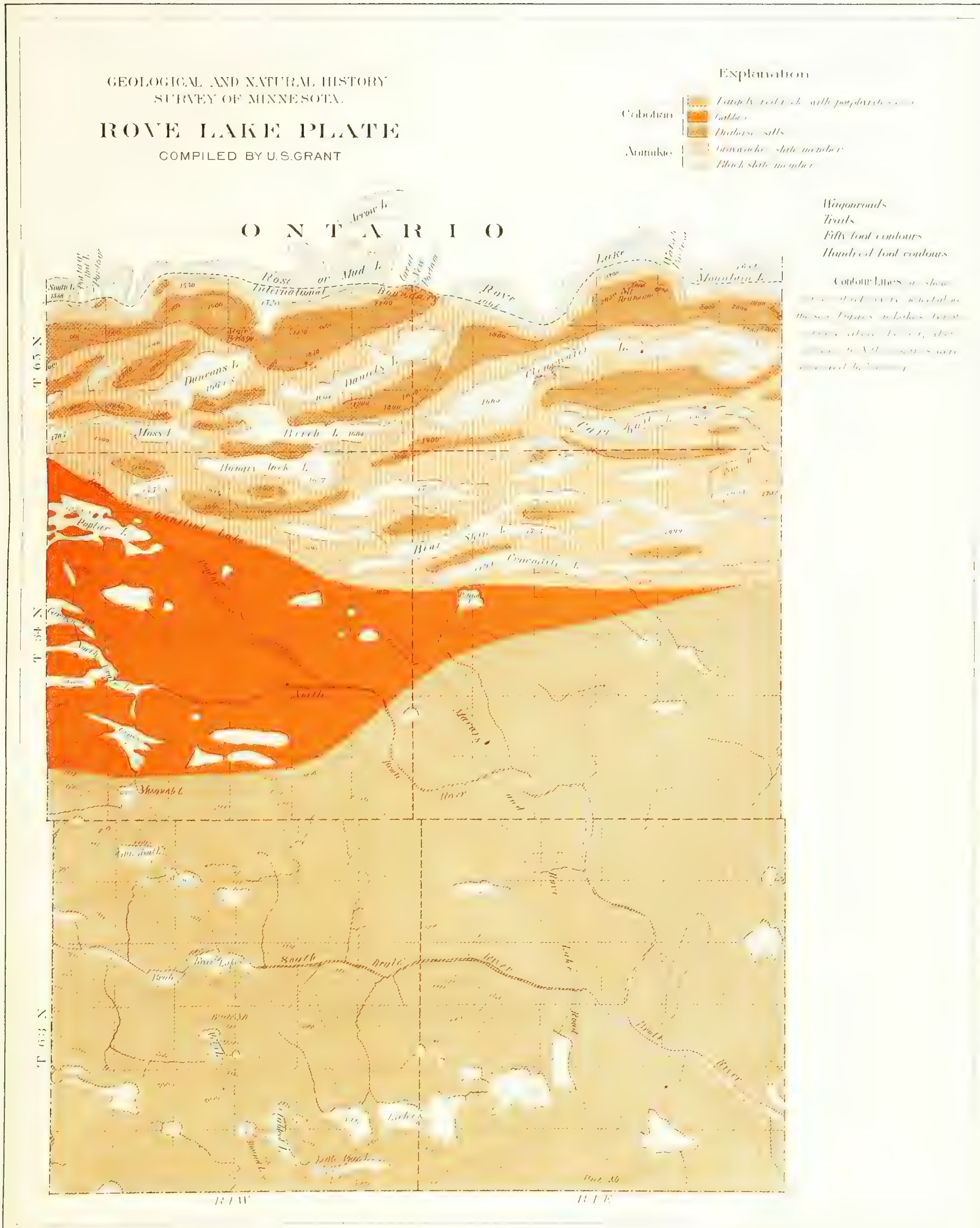
GEOLOGICAL MAP.

The contour lines in the area of the Animikie rocks are approximately correct. It may be stated that the contour lines here and in the vicinity of the iron-bearing rocks in the Akeley Lake plate are more nearly correct than elsewhere in Cook and Lake counties. The boundary lines between the diabase sills and the Animikie are in some cases drawn from topographic data. The northern limit of the Keweenawan granite is only approximate. Otherwise, the geological boundaries are fairly correct.

ROCK SAMPLES.

The following rock samples have been collected within the area of the Gunflint Lake plate. This list includes the specimens collected in Canadian territory adjoining this plate:

N. H. Winchell's series: Nos. 304–312; 693–714; 717–727; 1270–1317; 2051; 2054–2061.
A. Winchell's series: Nos. 655B, 656B; 657–659; 674–749; 777–821.
H. V. Winchell's series: Nos. 433–445A.
U. S. Grant's series: Nos. 8–42; 46–60; 170–201; 951, 952; 962; 967–967F; 970–1008C.
A. H. Elftman's series: Nos. 527–555.


GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA.
ROVE LAKE PLATE
COMPILED BY U.S.GRANT
Explanation
Cabotian
Gabbro
Diabase sills
Animikie
Graywacke slate member
Black slate member
Wagonroads
Trails
Fifty foot contours
Hundred foot contours
Contour Lines
ONTARIO
Arrow L.
Rose or Mud L.
International Boundary
Rove Lake
Mountain L.
Mt Brunson
Duncans L.
Daniels L.
Clearwater L.
Moss L.
Birch L.
Hungry Jack L.
Poplar L.
Gunflint Lake
Bearskin L.
Caribou L.
Greenwood L.
North
Poplar
North Brule River
South Brule River
Lake
Road
Lakes
T 65 N
T 64 N
T 63 N
R 1 W
R 1 E

CHAPTER XXVI.

THE GEOLOGY OF THE ROVE LAKE PLATE.*

By U. S. GRANT.

Situation and area. The Rove Lake plate is situated in the centre of the northern part of Cook county and borders on Canadian territory. On the west is the Gunflint Lake plate (No. 82) and on the east the Mountain Lake plate (No. 84). The Rove Lake plate includes Ts. 63-1 E., 63-1 W., 64-1 E., 64-1 W., 65-1 E. and 65-1 W. of the fourth principal meridian, but the last two townships are not complete, running into Canadian territory. The plate, inclusive of water surface, contains approximately 175 square miles.

SURFACE FEATURES.

Topography. Here we have the same three types of topography as in the plate to the west (Gunflint Lake plate)—a southern, a central and a northern. The first occupies the southern half of the plate. Here are several marked hill ranges running nearly parallel with each other and extending east and west. They are in the main composed of red granitic rocks. The most southern range is the one crossed by the Grand Marais and Rove Lake road at the southern edge of T. 63-1 E.; the ridge is at this place known as Pine mountain. Farther west, especially along the south side of Little Pine lake, it is more marked, and reaches an elevation of 2,000 feet in one place. Along the south side of South Brulé river is another of these ridges which is 2,150 feet high near the west line of T. 63-1 E., and which culminates in Brulé mountain, three miles to the west. As determined by level the summit of this hill is 2,170 feet above sea level. It does not appear as a very noticeable ridge from the south, but on the north it descends very rapidly to the Brulé River lakes, which are 521 feet below the summit. On the south of Brulé mountain is lake Abita—2,048 feet above tide—the highest recorded lake in Minnesota, but the pond just to the east is

* The area of this plate has been visited by different parties of the survey and most of the field notes have been published. The individuals who made the examinations, the dates of the work and the places of publication are as follows: N. H. WINCHELL, field work of 1878, *Seventh Annual Report*, pp. 17, 18, and *Ninth Annual Report*, pp. 77, 80; field work of 1879, *Tenth Annual Report*, pp. 66-69, 74-79; field work of 1887, *Sixteenth Annual Report*, pp. 61-64; field work of 1896, *Twenty-fourth Annual Report*. A. WINCHELL, field work of 1887, *Sixteenth Annual Report*, pp. 273-280.

No detailed work has been done within the area of this plate and our information concerning it is much less exact than is the case with the two plates to the west. The information at hand has been collected chiefly from trips (1) Along the Grand Marais and Rove Lake road, (2) Through Little Pine, Clubfoot, Abita, Brulé River and Little Trout lakes and the lakes in the western part of T. 64-1 W., and (3) Along the lakes of the international boundary. The author has done no field work within the area of this plate, but has passed through parts of it.

probably a few feet higher. The Misquah hills extend along the south side of T. 64-1 W., and have already been mentioned in the description of the Gunflint Lake plate as running along the south side of T. 64-2 W. In this hill range east of Misquah lake, at the southeast corner of sec. 32, T. 64-1 W., is the second highest point known in the state—2,223 feet, as determined by level.

The central type of topography, comprised in the comparatively level district underlain by the gabbro, is well developed in T. 64-1 W., especially in the district lying between Cross and Poplar lakes.

The northern type of topography is characteristic of the northern third of the plate, and has been mentioned with some detail in the description of the plate to the west (Gunflint Lake plate). It consists of the parallel, east and west ridges, capped by diabase sills and underlain by Animikie slates, which have steep mural escarpments on the north and gentle slopes on the south. This type of topography is here even more strikingly developed than in the Gunflint Lake plate. The most pronounced hills of this type are those seen along the south shores of the international boundary lakes. At Rose lake these hills are nearly everywhere more than 300 feet above the lake level, while at Rove and Mountain lakes they are still higher, reaching 400 feet or more above these lakes. Two quite prominent peaks occur in this hill range, one known as Rose Lake mountain and the other as mount Reunion. The first is south of Rose lake, at the western side of sec. 21, T. 65-1 W. and is 1,997 feet above sea level or 469 feet above the lake (see figure 2 of plate NN). The second, mount Reunion, is south of Rowe lake in the western part of sec. 22, T. 65-1 E. A photograph of this hill, taken from the northwest, is shown in figure 3 of plate NN. The top of the talus slope was found by aneroid barometer to be 210 feet above Rove lake. This talus is composed of large angular fragments of slate and diabase; many of these fragments shown in the photograph are ten to fifteen feet across. Above the talus is a cliff whose vertical face is about 200 feet, or possibly more, making the hight of the summit over 400 feet above Rove lake or approximately 2,075 feet above the sea. The lower half of the cliff is composed of Animikie slates and slaty quartzytes, and the upper half is a diabase sill (No. 2064) which presents a columnar appearance, although this also extends into the slate. The line of junction between the slate and diabase can be seen in the photograph.

The lowest water in this area, Rose lake, is 1,528 feet above sea level, and the highest point, the hill less than a mile southeast of Misquah lake, is 2,223 feet, making a difference between the extremes of altitude of 695 feet.

Drainage. The area of the Rove Lake plate lies in the drainage basin of the gulf of St. Lawrence, and the waters drain into lake Superior through the Pigeon and Brulé rivers. The former stream carries the waters of the lakes in the Animikie

area, but some of these, as Rose and Duncans lakes, empty into the Arrow river, a tributary of the Pigeon. The lakes south of the Animikie area are all drained through the Brulé river.

The drift. Drift deposits in this area are more extensive than in the three plates to the west, yet outcrops of the underlying rock are not scarce, especially along the north side of the hill ranges. In Ts. 63–1 E. and 64–1 E. the mantle of drift is somewhat thicker than elsewhere in this plate, and is composed in large part of material of local derivation. North of the North Brulé river, in secs. 20, 29 and 30, T. 64–1 E., are some morainic hills, and these have been thought by Mr. Warren Upham to belong to the eleventh (or Mesabi) of the Minnesota moraines. There are drift hills also between Rove and Rose lakes, and on the portage between these lakes is a noticeable kame.* The general ice-motion, as last recorded, was approximately from the north.

GEOLOGICAL STRUCTURE.

The Animikie. The black slate member of the Animikie is found only over a small area in this plate. As far as known it is confined to a narrow belt along the south sides of South and Rose lakes, and passes into Canadian territory at the east end of the latter lake. It probably extends for some distance north of the international boundary line, running at least to Arrow lake (see rock No. 302).

The remainder of the Animikie area, which runs as far south as the south side of Crocodile lake and is here about five miles in width (from north to south), is underlain by the quartzyte and slate member and the diabase sills. At mount Reunion this member of the Animikie forms a large part of the perpendicular cliff already mentioned (see figure 3 of plate NN), and specimens collected here (Nos. 2062 and 2063) are fine-grained quartzytes or quartz slates, quite characteristic of this member of the Animikie.

The Animikie strata lie nearly flat or dip in general towards the south or south-southwest at a very low angle. The average dip is less than in the Gunflint Lake plate. There is also evidence of faulting in the Animikie in the Rove Lake plate, but this has not been worked out in detail. While the general dip of the Animikie is as above stated, there are some exceptions, as noted in the following paragraph:

"On the portage from Clearwater lake to Mountain lake the trail passes over an interval near the summit of the divide where the quartzyte dips northwest. Several short, low, sharp mono-clinals occur, crossing the trail diagonally. They are inconspicuous compared with the mono-clinals dipping in the other direction. The high hill, however, facing on Mountain lake, just east of where the trail strikes it, dips in the opposite direction. Another point where the slate dips northwardly may be seen along the east end of Caribou lake on the north side."†

The diabase sills of the Animikie, which have been discussed in the description of the Gunflint Lake plate, exist here in large numbers. Some of them, especially

*See page 837 of this volume.
†N. H. WINCHELL. *Ninth Annual Report*, p. 79.

that along the south side of Rose lake and that along the south side of Rove and Mountain lakes, form very prominent features of the land surface. The first of these appears to pass into Canadian territory between Rose and Rove lakes,* and it, as well as the second, is in places over 100 feet thick.

The Keweenawan. In this plate the rocks of the Cabotian division of the Keweenawan are separated into two groups, the gabbro and the red rock. The gabbro is seen in typical development about Cross, North Brulé, Caribou and Poplar lakes, in the western part of T. 64–1 W. To the east of these lakes the gabbro area has not been examined carefully, and the limit of the eastward extension of the typical gabbro is not known definitely. It has been reported from the Grand Marais and Rove Lake road, in the eastern part of T. 64–1 W., and also near the trail which runs from this road to Round lake, in the western part of T. 64–1 E., but specimens have not been collected from these places. The mapping of the gabbro to the east of the western part of T. 64–1 W. is accordingly somewhat uncertain.

South of the gabbro is a considerable area which is underlain in large part with "red rocks." These vary considerably in grain and in composition, and have associated with them more basic rocks, such as diabase. From the available information it is not possible to separate with certainty the different parts of this red rock series. In some places the rocks are quite acid, and may be termed granites. Close by there are other coarse-grained rocks, still red in color, which are more basic, and may be altered gabbros (Nos. 644, 648, 649, 674, 675). The relations of these two facies of what is mapped as red rocks are not known. In places, as near Misquah lake, the red rocks evidently are surface volcanics (Nos. 647, 653, 685, 687, 1265), and some show the secondary micropoikilitic groundmass which is so common among the aporhyolytes and apotrachytes found on the lake Superior shore.

Associated with these red rocks are other more basic rocks, porphyrytes and diabases. These seem to occupy a belt just to the south of the Misquah hills, and are also found further west at Brulé lake. In this belt two sections were taken, which are as follows:

Section 1.† Near Little lake on the north edge of sec. 8, T. 63–1 W. In descending order.

Red granite (not actually seen in place).

No. 678. A diabase of medium grain, somewhat decayed. Fifteen feet.

No. 679. A rock with a black, aphanitic groundmass in which are red porphyritic feldspars. The groundmass is decayed, but the rock seems to be a diabase porhyryte. Four feet.

No. 679A. Same as No. 679 except that the porphyritic feldspars are, in the main, gray, instead of red. Eight feet.

No. 680. There are two specimens of this; one is dark-red in color, is very fine-grained, seems to be amygdaloidal and is somewhat porphyritic with small feldspars. The other specimen seems to be fragmental and the section shows apparently a tuffaceous rock made of glass fragments now deritrified. Eighteen feet seen.

The dip of the above beds is 10° towards the southwest.

Section 2.‡ Hill on right of portage from Little lake to Little Trout lake, sec. 5, T. 63–1 W. In descending order.

* There is a possibility that the two sills are the same and are continuous from Rose to Rove lakes.

† N. H. WINCHELL. *Tenth Annual Report*, p. 76.

‡ *Ibid.*, p. 77.

No. 681. A very fine-grained black rock composed largely of small plates of feldspar. Twenty feet seen.

No. 682. A diabase porphyryte with large porphyritic feldspars, red to gray in color. On the side of one of the specimens is a small mass of black rock looking like a suddenly cooled diabase. Thirty-five feet.

No. 683. A medium grained diabase. Twenty feet. Below is a talus of fifty feet where the rock is unknown.

No. 684. A considerably finer diabase. This occurs further north and is in a layer four feet in thickness included between some of the beds of porphyryte (No. 682) near the bottom of the same.

The dip of the above beds is 20° towards the southeast.

GEOLOGICAL MAP.

The contour lines in the western half of the plate are approximately correct, but elsewhere contours are largely omitted on account of lack of data for drawing them. The geological boundaries can be regarded as only approximately correct as our information concerning this plate is much less than for the two plates to the west. In some instances the diabase sills in the Animikie are located entirely by topography.

ROCK SAMPLES.

The following rock samples have been collected within the area of the Rove Lake plate:

N. H. Winchell's series: Nos. 301, 302; 644-653; 670-692; 1265-1269; 2062-2065.
A. Winchell's series: Nos. 750-756.
A. H. Elftman's series: Nos. 292-295.

CHAPTER XXVII.

THE GEOLOGY OF THE MOUNTAIN LAKE PLATE.*

BY U. S. GRANT.

Situation and area. The Mountain Lake plate is situated on the northern side of Cook county and borders on Canadian territory. On the west is the Rove Lake plate (No. 83), and on the east the Pigeon Point plate (No. 85). The Mountain Lake plate includes Ts. 64–2, 64–3, 64–4, 65–2 and 65–3, all east of the fourth principal meridian. All except the first are incomplete townships, running into Canadian territory. The plate, inclusive of water surface, contains approximately 110 square miles.

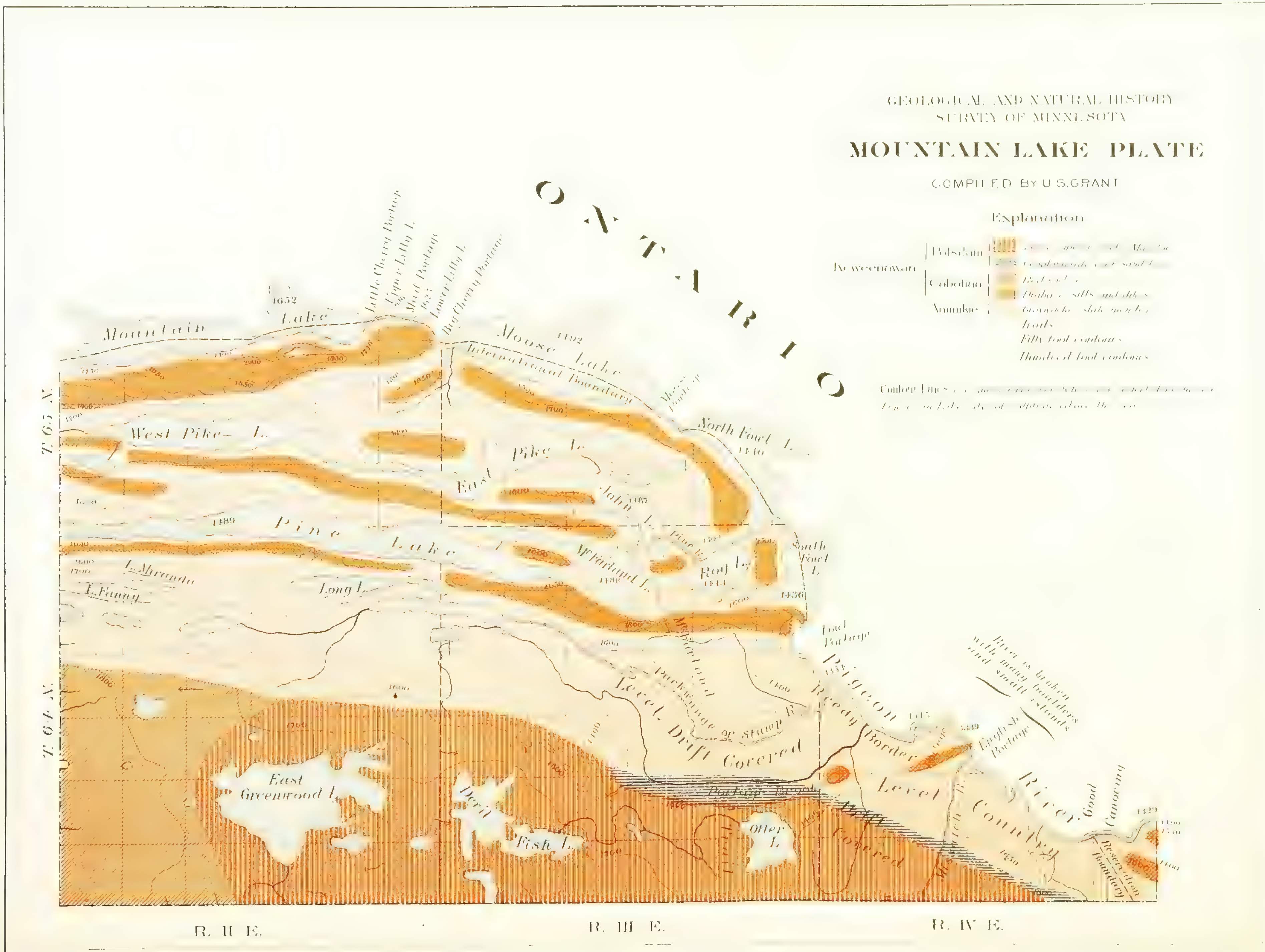
SURFACE FEATURES.

Topography. The northern part of the plate has the surface common to the Animikie area in Cook county, *i. e.*, east and west ridges, with steep or precipitous northern sides and gentle slopes on the southern sides. These ridges are capped by diabase sills, and in the valleys between the ridges are elongated lakes. (For an account of this kind of topography, see description of the Gunflint Lake plate.) The most prominent of these ridges is the one lying just to the south of the international boundary, and rising 300 or more feet above the lakes to the north. South of Mountain lake on the line between secs. 21 and 22, T. 65–2 E., this ridge is 353 feet above that lake, while a few rods further west the land rises fifteen feet higher, or 2,020 feet above the sea. In figure 4 of plate NN, a section through one of these diabase crowned hills is shown. This is at the east side, near the south end of South Fowl lake. About one-third of the hight of this hill is composed of Animikie slates, dipping south at an angle of about 8°. These slates are visible and most accessible on the north face of the bluff. The rest of the hill is composed of diabase, showing a perpendicular jointage. Near this hill, and at the north end of the portage which leads southward along the Pigeon river, is a spring, described as follows:†

*The area of this plate has been visited by the survey parties at different times and part of the field notes have been published. The individuals who made the examinations, the dates of the work and the places of publication are as follows: N. H. WINCHELL, field work of 1878, *Seventh Annual Report*, pp. 18–21, and *Ninth Annual Report*, pp. 74–79; field work of 1893, not published; field work of 1896, *Twenty-fourth Annual Report;* see, also, *Amer. Geol.*, vol. xx, pp. 50, 51, July, 1897. A. WINCHELL, field work of 1887, *Sixteenth Annual Report*, pp. 279–289.

The information available concerning this plate was obtained principally from visits (1) Along the international boundary; (2) To Pine lake and lakes Miranda and Fanny; and (3) To the conglomerate in the N. ½ sec. 26, T. 64–3 E. The writer has not done any field work in this plate, but has visited parts of it.

† N. H. WINCHELL. *Ninth Annual Report*, pp. 74, 75.


GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA
MOUNTAIN LAKE PLATE
COMPILED BY U.S.GRANT
Explanation
Keweenawan
Potsdam
Cabotian
Animikie
ONTARIO
Mountain Lake
West Pike L.
East Pike L.
Pine Lake
Moose Lake
International Boundary
North Fowl L.
South Fowl L.
John L.
McFarland L.
Royal L.
Long L.
L. Miranda
L. Fanny
East Greenwood L.
Devil Fish L.
Otter L.
Little Cherry Portage
Upper Lilly L.
Mud Portage
Lower Lilly L.
Big Cherry Portage
Fowl Portage
Pigeon River
Reedy Border
Level Drift Covered
Level Country
Drift Covered
Portage Brook
English Portage
River is broken with many boulders and small islands
Good Canoeing
Reservation Boundary
T. 65 N.
T. 64 N.
R. II E.
R. III E.
R. IV E.

At the foot of this hill, on the west side, is a copious talus, which also lies in a shaded gorge which slopes north and is protected from the warm sun of the summer. At the foot of this talus, where this gorge approaches the lake, near the end of the trail, is a spring of ice-cold water, which is said to never dry up, nor to become warmer. It is probably fed by perpetual ice protected in this gorge from the warmth of summer by the coarse fallen pieces of the talus. The presence of this perpetual ice is further indicated by the rank mosses growing on the rocks about, sustained by the condensed moisture due to the coolness of the gorge.

In the southeasern part of the plate, the diabase capped hills are perhaps due to diabase dikes cutting the Animikie, rather than to sills. Just to the south of Portage brook there is a prominent ridge of basic igneous rock, but it is not known whether this is a dike or a sill.

To one traveling eastward along the international boundary, a marked change in the topography appears immediately after leaving the hill on the south of South Fowl lake. Beyond this point, the Pigeon river, instead of being a series of lakes, is a river flowing between low banks. The surface, instead of being rough and rocky, is approximately level, and drift-covered. It would make excellent farming land.

The drift. The northern part of this area is similar to much of the northern part of Cook county, a country where drift is scanty, and in places lacking altogether. But eastward from South Fowl lake the valley of the Pigeon river has an abundant covering of drift, and rock outcrops are uncommon; in fact near English portage are the only outcrops along the river in the area of this plate. There seems to be evidence of a moraine passing through the southern part of this plate, and there are drift hills at the first portage west of English portage. Mr. Warren Upham has mapped the eleventh or Mesabi moraine as extending through the southeastern corner of this plate.* But there is evidence, which has been especially brought out by Mr. A. H. Elftman, that the moraine here existing is not part of the Mesabi moraine, nor of any terminal moraine forming the southern border of the ice-sheet, but that it is a lateral moraine formed along the border of an ice-lobe which extended from the northeast and moved southwesterly through the lake Superior basin.†

GEOLOGICAL STRUCTURE.

The Animikie. Strata of this age occupy more than the northern half of the plate, and are supposed to extend eastward along the Pigeon river from South Fowl lake, although exposures of these rocks are not found along this part of the river in the area of this plate. The Animikie strata belong to the upper or graywacke slate member, and are composed of siliceous slates and fine-grained slaty quartzytes. One type of rock, which is different from the rest of the Animikie rocks, needs to be mentioned in this connection. This is a fine-grained, soft, greenish gray shale or slate which is found near the Keweenawan conglomerate in the northern part of sec. 25, T. 64–3 E. This rock apparently underlies this conglomerate (although it

* *Twenty-second Annual Report*, plate 1.
† See description of the drift features in the chapter on Cook county.

may possibly be part of the same formation as the conglomerate), and reaches a considerable development towards the east in the Pigeon Point plate, where it is described as the Grand Portage graywacke.

The Keweenawan. The diabase sills of the Animikie are referred to the Cabotian division of the Keweenawan. They are of the same rock and hold the same relations to the Animikie as do the same sills farther west, especially in the Gunflint Lake plate, and need not be further described here. At the south side of South Fowl lake, and along the northern edge of the plate east of this point there is some evidence to show that the diabase masses, instead of being in the form of sills, are really large dikes, such as those so characteristic of the Pigeon Point district (see chapter xxviii).

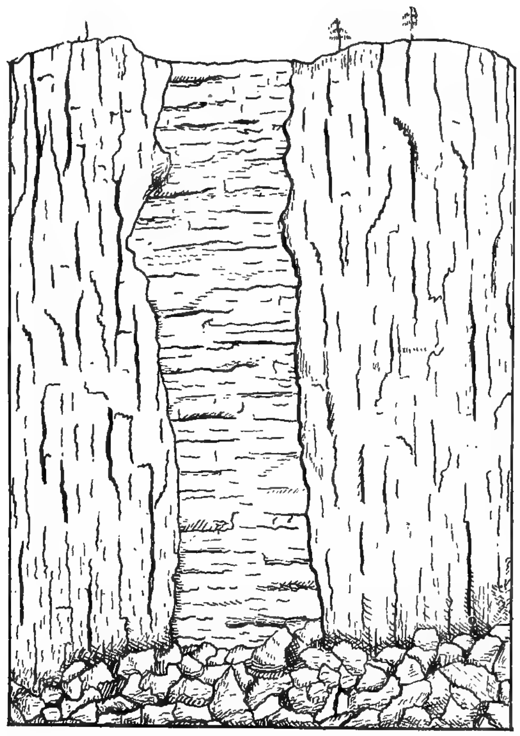


FIG. 90. HORIZONTAL COLUMNAR STRUCTURE IN THE DIKE ON THE SHORE OF SOUTH FOWL LAKE.
The dike intersects diabase having a vertical columnar structure.

At the outlet of South Fowl lake, on the west side, is a cliff of diabase in the form of a sill (or perhaps a dike) rising 200 feet above the lake. This cliff has a vertical, eastward-facing escarpment of about 120 feet. In the midst of the face of the cliff is a vertical dike, twenty-seven feet wide, exhibiting a horizontal bedded or quasi-columnar structure. The columns are six to ten inches thick, and, placed between the vertical columns of diabase, present from the lake the appearance of a tier of shelves. The dike rock is a fine compact diabase. The above cut shows a sketch of this dike. The dike rock is represented by rock samples Nos. 767W

and 1898, while No. 1899 is the finer facies of the same on the edge of the dike. The main mass of diabase is shown by Nos. 765W and 1900.

On the northward slope of the ridge, which lies just to the south of Portage brook, in the N. ½ sec. 25, T. 64–3 E., are exposures of a conglomerate and sandstone which are referred to the base of the upper division of the Keweenawan. The best exposures are along and to the west of a small northward flowing creek, a tributary of Portage brook. At one place this little stream has exposed a considerable amount of the conglomerate, and here there is a thickness of about eighteen feet of coarse conglomerate (No. 1903) overlain by a like thickness of finer conglomerate (No. 1902). Farther south up the slope of the hill is some sandstone or fine coglomerate (No. 1904) and the total thickness of this formation here is estimated to be at least 126 feet. The dip is about 12° towards the south-southwest. The coarser part of the conglomerate, whose actual base is not exposed, contains numerous well-rounded pebbles of all sizes, up to those six or more inches in diameter. The pebbles are largely of a gray to greenish or pinkish granular quartzyte, and of white vein quartz. Other, but much less abundant pebbles, are of gray shale, yellowish flint, black flint, banded greenish flint, very fine-grained, slaty quartzyte and apparently red taconyte. Most of these pebbles, especially the taconyte, can be matched in the Animikie strata.

To the south of the conglomerate, and near the top of the hill, are some basic rocks which are thought to overlie the conglomerate, and are referred to the Manitou division of the Keweenawan. One of these (Nos. 1905 and 2066) is a rather fine-grained, dark rock, more or less decayed and holding amygdules of chalcedony. South of this is a coarser-grained, porphyritic rock (No. 2068), possibly a facies of the amygdaloid, but not amygdaloidal.

ECONOMIC RESOURCES.

In Canadian territory, not far north of this plate, considerable exploration and mining of silver has been carried on, but at present the work is abandoned. In the area of this plate apparently the same geological conditions exist as in the Canadian district, and similar argentiferous veins have been noted. Some of these were visited in 1878 by the state geologist and the following description is taken from his report.* As this chapter is being written (July, 1897) the newspapers state that active steps are being made towards a thorough exploration of the "ancient diggings" mentioned below:

William P. Spalding has a mining location on the south side of lake Miranda, which is a narrow long lake next north of lake Fanny, and on sec. 5, T. 64–2 E. This vein is strong, but not well defined. His work consists of several shallow pits for the purpose of ascertaining more definitely the position, direction and dip of the vein. What can be seen of it consists largely of breccia of trap, or of quartzyte recemented with quartz, in small, often

* *Seventh Annual Report*, pp. 18–21.

drusy crystals. It is six or eight feet wide, and occurs, like others, along the north side of a quartzyte mono-clinal, and is largely hid by the talus materials. Mr. Spalding says he has taken out several pieces of native silver, but none was seen in the fragments thrown out.

On the other slope of this mono-clinal, south of the above, is another fracture, which seems likewise to have taken the nature of a vein. Some working on this slope disclosed the existence of the fracture, and large float pieces of vein material indicate the contents, but the work had not gone far enough to precisely define its location and extent.

Mr. Spalding's "ancient diggings," so-called, consist of a series of depressions running along the supposed position of the first vein above mentioned, so as to make in some places a continuous trench. In some parts there are two ridges, with an irregular depression between them somewhat semi-lunar, so that it unites again with the main depression. One of these ridges, that nearest lake Miranda, consists of clay and angular pieces of quartzyte; like talus debris, largely decomposed, but the other is of angular blocks, and Mr. Spalding says contains vein material, as if thrown out of the depression in excavating on the vein. These depressions show some openings within, between large boulders, and nearly large enough to admit a man, and, after clearing out a little, one was followed downward some feet. As yet no ancient hammers or implements of any kind have been found in the vicinity.

As to the cause of the depressions and parallel ridges, there may be three different explanations. Sufficient data are not at hand for affirming either.

1. They may be due to ancient mining, as supposed by the owner, though the discovery of hammers, or other implements, is necessary for the demonstration of this hypothesis. It is also true that the ancient mining hitherto discovered in the lake Superior regions has been wholly for native copper, of which implements have been found in ancient works as far south as the state of Georgia, but, so far as known, no silver implements have been found having so old a date; and the ancients seem to have had no knowledge of any process for reducing the ores, the silver in this formation occurring mainly as argentiferous galena.

2. The depressions may be due to the solution and removal of the contents of a large vein under natural processes, and the consequent settling of the surface. When two depressions run nearly parallel in that case, the vein may branch out and become double, uniting again when the depressions unite. Then, also, the upper ridge, nearer the bluff, would naturally contain coarser pieces than that nearer the lake, which is true. Veins are thus dissolved sometimes, and sunken in for some distance, as the large baryta vein on Pigeon point. This cause, if true, indicates a strong vein, and one that, with the quartz now remaining as the sole matter undissolved, must be charged with soluble minerals, and perhaps with very valuable ores. Deep shafting alone will determine it. So far as exposed, however, the quartz remaining now undissolved is sufficient to form a firm frame-work, capable of supporting the overlying materials so as to prevent such a collapse of the surface as here supposed.

3. These ridges may be of the nature of ice-ridges or moraines. There are a great many instances of ridges thrown up by the ice of lakes through alternate freezing and thawing both in Minnesota and Iowa, and sometimes such have received the name of "walled lakes." But aside from this, the ice of the last ice-period may have lain, for a long time prior to its final disappearing, in the rocky valleys of the northern part of the state, as suggested by Mr. John Lightbody. Its effect, along a rocky bluff, would be to form low, blind ridges of debris or morainic material, which would remain more or less distinct to the present under favorable conditions. In that case the coarser nature of the ridge nearer the bluff would be due to the fallen pieces from the bluff itself, while the clay of the ridge nearer the lake may have been due to drainage in that direction and to the crushing action of the ice in times of expansion. The level of the ice would remain nearly constant under the same causes which now keep the level of the water nearly constant.

These considerations are here mentioned, as there seems to be a tendency at other places in the northern part of the state to attribute such phenomena to ancient mining, perhaps without sufficient reason.

John McFarland's location is on secs. 9 and 10, township 64 north, range 3 east. He has two veins, and one place thought to be a site of ancient mining, in all respects similar to that of Mr. Spalding, except that this series of ridges and depressions is not near any lake at present, but alongside a bluff enclosed in a valley. If a vein should be discovered at this locality, then Mr. McFarland has three distinct veins situated on different sides of a mono-clinal hill, viz., one on the north side, one on the south side and one on the east side, the last being that in which are the supposed ancient diggings. These are all close together, and the east and west veins are all well marked, running also across the adjoining valleys and appearing in the next hills. They are outwardly of quartz and brecciated quartzyte, and occupy faults between the slate and the trap of the country. Mr. McFarland has done no work on his veins, but is occupied in farming and fur catching.

Johnson's working is on a vein situated, as nearly as could be ascertained, on S. E. ¼ sec. 32, T. 65-3 E. This is also on the south slope of a hill, but has trap on the north side and slate on the south side, being really in a fault like the rest; but the slate is here brought up, like the south vein at Spalding's, on a line nearly parallel with the upper surface of the trap. This vein shows mainly calcite, but has also quartz, pyrite, galenite and native silver. These can be seen in the dump near the shaft. There is also, as in nearly all the other veins seen, a large amount of brecciated quartzyte and siliceous slate. This is here mainly on the south side of the vein, while the north side is in a similar manner filled with breccia of trap. This appears to be a strong vein, and one that promises well.

McFarland, Rice and Ramsey have a very conspicuous and strong vein near the shore of Pine lake, on S. E. ¼ sec. 31, township 65 north, range 2 east. This has not been worked, but slightly uncovered in two places. It

has an irregular direction, width and appearance, large white masses of calcite and quartz lying about promiscuously, apparently in place, over a width of several rods north and south. Where it has been uncovered it is also mixed with a breccia of quartzyte and has a width of ten or twelve feet. It seems to have trap on the north side, but it is not well exposed. A trap bluff rises abruptly toward the northwest, facing east and south, and the vein is in a lower level, having a zigzag course, governed, apparently, in direction and deflected by that upheaved trap and slate along its western extent, so far as it is visible; but further east it has a more uniform course in consonance with the general trend of the hills; yet this, like Spalding's second and one of McFarland's, is on the southward slope of the main hillside. The calcite and quartz, not mentioning the breccia, are the most abundant gangue-rock. The ores are pyrites (said to be auriferous), galenite, sphalerite and chalcopyrite. These, with the exception of the galenite, can be made out in examining the pieces in the dump.

GEOLOGICAL MAP.

The data, both for the contours and for the geological boundaries are comparatively few. The contours can be considered only as indicating in general the position of the ridges. The geological boundaries are located only approximately, and future work may alter them materially.

ROCK SAMPLES.

The following rock samples have been collected within the area of the Mountain Lake plate:

N. H. Winchell's series: Nos. 297-300; 303; 1898–1906; 2066-2072.
A. Winchell's series: Nos. 762–769.

CHAPTER XXVIII.

THE GEOLOGY OF THE PIGEON POINT PLATE.

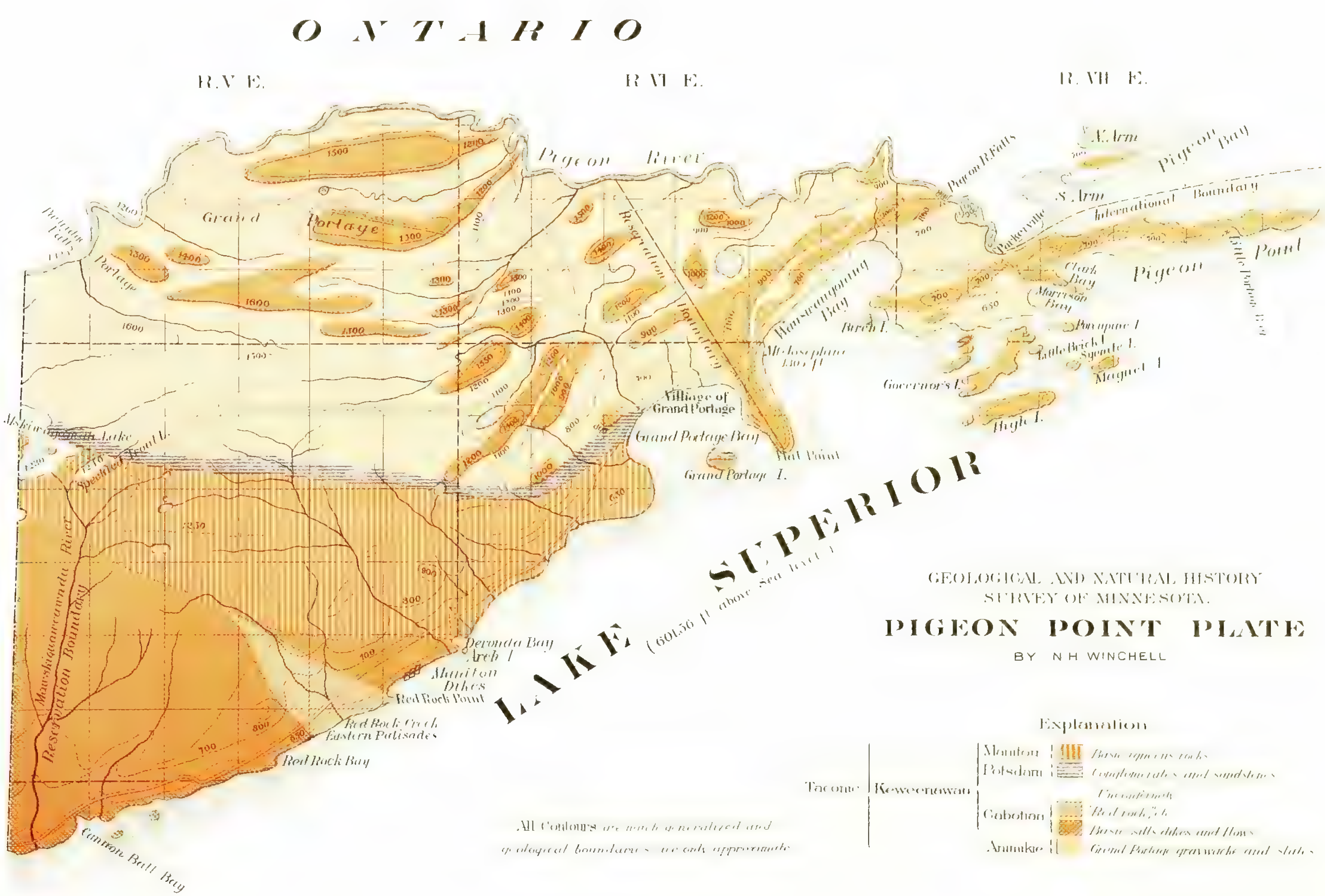
(PLATE 85.)

BY N. H. WINCHELL.

Some of the earliest records of travel and discovery within Minnesota are connected with the small area comprised within this plate. The earliest French voyageurs and fur-traders passed over the Grand Portage trail, and at Grand Portage at a later date was a village which was constantly active with the arrival and departure of parties bound up with supplies for the region of the Lake of the Woods and lake Winnipeg, or down with furs destined for Montreal and for Europe. The trail was a well-kept road, over which wheeled vehicles, drawn by oxen, were continually passing. The Indians and half-breeds of the present day have only traditional knowledge of this traffic and of the scenes which it entailed. A strong blockhouse or fort, the ruins of whose foundation are still pointed out, stood near the dock at Grand Portage (plate OO, figure 6), surrounded by the usual residences and accompaniments of a trading station of the Hudson Bay company, and within the village were often gathered, during the winter season, the subordinate officers, *coureurs des bois* with their families, and the dependent Indians, to the number of several hundred or a thousand souls, while others, more hardy and venturesome were engaged in the winter hunt. The place was known as Fort Charlotte. At the upper end of the portage was another similar establishment, and its ruins are still visible in the form of foundations that retain indistinctly their outlines, and in the old dock, made of cedar logs,* which is held in place in the muddy bank of the river, and still serves as a landing for canoes. This is a chapter in the history of Minnesota which is yet unwritten. Its tragic and venturesome events, the commingling of the colonial civilization, represented perhaps poorly by the officials of

*In 1893 there were sixty-seven cedar logs projecting from the bank near the level of the water, in the form of a platform, supported on other cedars running in the other direction and on stones. There were doubtless many more originally. They are decayed and frayed at the ends but permanently kept in place by the overlie of red clay on the landward ends.

There were two "forts" here, houses, barns for horses and cattle (with which the grand portage was made) and all the accoutrements of a great station of the Hudson Bay company. One of my men (in 1893) was a grandson of Francis Xavier Pireau, still living at Marquette over ninety years of age, who was a voyageur for that company, and he recounted many incidents he had heard from his grandfather relating to this trail. The officers of the company, according to his testimony, were heartless, hard on the men, domineering, exacting and cruel, and guilty of many things, even crimes, which could not now be enacted and go unpunished.



GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

PIGEON POINT PLATE

BY N. H. WINCHELL

Explanation

Taconic	Keweenawan	Manitou		Basic igneous rocks
		Potsdam		Conglomerates and sandstones
				Unconformity
		Cabotian		Red rock, &c.
				Basic sills, dikes and flows
		Animikie		Grand Portage graywacke and slates

FIG. 1. COMING TO THE PORTAGE LANDING.

FIG. 2. IN SHOAL WATER.

FIG. 3. LEAVING THE CAMP.

FIG. 4. GRANITE BOULDER LYING ON THE CRUMPLED JASPILYTE OF THE NORTH RIDGE, SOUDAN. (p. 523.)

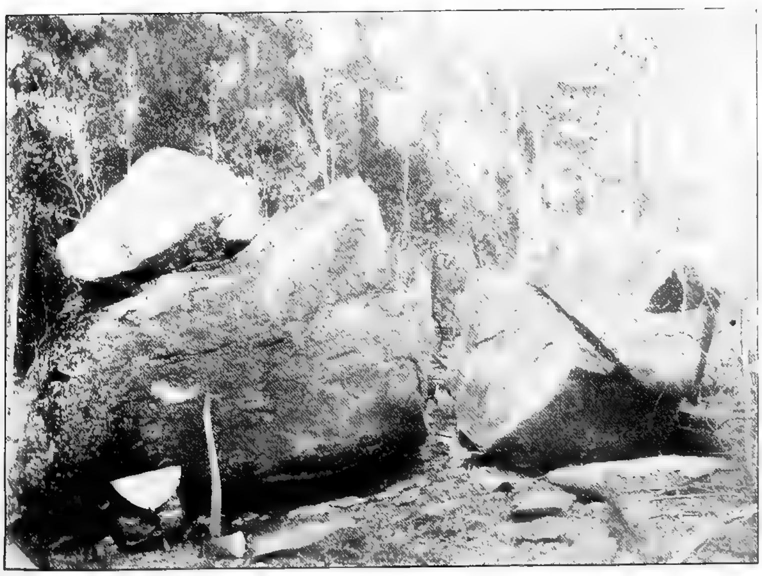


FIG. 5. ROCKING STONE ON A BOULDER SPLIT BY FROST, NEAR MAYHEW LAKE.

FIG. 6. THE DOCK AT GRAND PORTAGE. (p. 502.)

the frontier and of the fur companies, with the simplicity and often the duplicity of the Indians, through a period of a hundred and fifty years, if well known, would constitute a romantic epoch of the pioneer history of the state. It began with the time of Duluth and of Grosselliers, of Verendrye and of Franquelin, extending from about 1675 to 1825. This area embraces the gateway between the domain of the Hudson Bay company on the north, and that of the Northern Fur company of Canada on the south.

Topography. There is no part of the state of equal size which is so mountainous. Along the northern boundary the Pigeon river descends, like nearly all the streams that enter lake Superior from Minnesota, rather suddenly from six to seven hundred feet. It presents below the commencement of the "grand portage" a continuous series of rapids and waterfalls, as far as Pigeon River falls, below which with some difficulty small canoes can float in the river to the head of Pigeon bay, which is a fine harbor for large vessels.

The hills that diversify the region are abrupt and rocky, consisting of great dikes of diabase and gabbro that lift their heads up through the slates which they penetrate, sometimes with perpendicular walls, from 50 to 200 feet above the slates which they cut. As these dikes, which are often several hundred feet wide, must have been confined between rock walls when the molten matter was intruded, there is evidence of the removal of that amount of strata of the Animikie, by circumdenudation, from the dikes. The hills are rudely arranged in ridges which extend easterly and northeasterly, though with exceptions the chief of which is the hill and peninsula of Hat point, which is at right angles to the prevalent direction. The individual hills are rather short. The upper contour line of one of these dikes rises and falls suddenly, as if the general fracture line shifted somewhat from place to place, and was occasionally obstructed. Toward the central and western portions of this area the surface is more moderately rolling or hilly, with some extended tracts that are plains. This is the character of the greater part of the N. E. $\frac{1}{4}$ T. 63–5 E., where the Indians from time immemorial have resorted annually to celebrate the spring festival of sugar-making. Here the country is nearly flat, and no hills are visible except in the distant horizon. The timber has not been destroyed by fire and much of it is birch and maple, this being probably the most northern locality, at least in northeastern Minnesota, where the sugar maple is found growing to large size.* The country about the lakes on the western border of T. 63–5 E. is

*The trees are scarred by repeated tappings, many scars having been entirely overgrown. A small oblique gash is cut so as to take out the bark, and about half an inch of the sapwood. Down the sides of this oblique gash the sap runs to the bottom, where it necessarily concentrates as the sides of the gash approach to a point. Just below this point a spout is inserted in another little ascending cleft made by a single blow of the hatchet, so placed that the sap runs onto it and drips from the end. This spout is simply a chip fashioned from a cedar splinter. Sometimes, instead of inserting the chip under each gash, several gashes are so connected by little leading-trenches that they all drain at the bottom of the lowest gash from the same spout. The sap is gathered in pails or basins made of birch bark by folding gently the ends of a long piece into two folds and passing a thong of willow bark.

The whole village moves up here the latter part of March, or first of April, and returns in May. They spend some time in getting ready, making birch basins, erecting temporary wigwams, etc., etc., and somewhat in hunting. It is a great event, and

of the same character. The country is drifted but generally elevated, being apparently about 600 feet higher than lake Superior, with only scattering hills that consists of the igneous rock of the region.*

In the southwestern part of this area another series of hills skirts along the lake shore, rising to the hight of 1,200 to 1,500 feet above the sea, and they are conspicuous from the lake. As they have not been examined, they are not located by contour lines on the accompanying plate. They also consist of dark-colored, and often coarse-grained trap rock, but whether in the form of dikes or of sills, or as flows of surface traps, or of all combined, is not known. They are believed, however, to be for the most part of later date than the dikes in the northern and eastern part of this area.

The sketch below shows the contours of the hills as they appear from Grand Portage island.

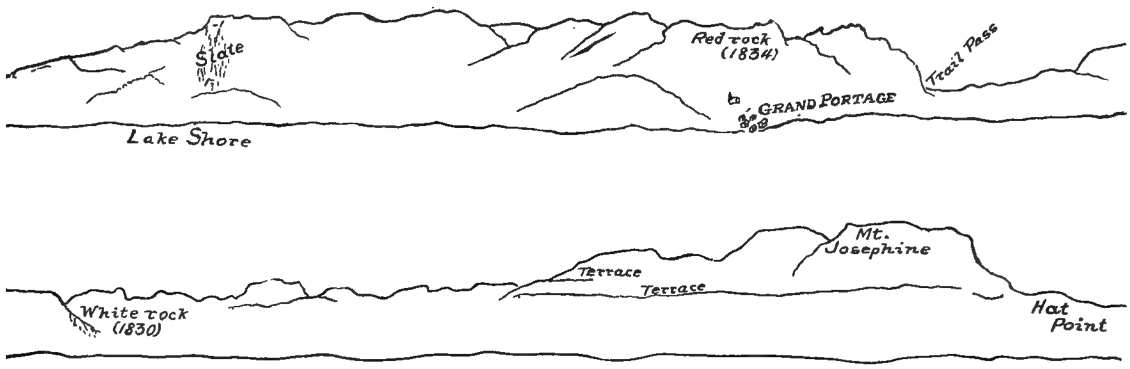


FIG. 91. OUTLINE OF THE HILLS AT GRAND PORTAGE FROM GRAND PORTAGE ISLAND.

FIG. 92. DISTANT VIEW OF HAT POINT FROM THE WEST.

The Grand Portage trail. In its present degenerated state, this is still a good road, except where the bridges over the streams have not been renewed. It is an international route,† and many American and Canadian parties passed over it until the construction of the Canadian Pacific railway. It will soon be a mere Indian trail,

no Indian would willingly forego the pleasure. It breaks up the winter's confinement and inaugurates the season of warmth and freedom and comfort. When the season is good and the family has the apparatus in sufficient quantity and readiness, one family can make from 500 to 600 pounds each season. When the season is bad they can make no more than enough to supply themselves. The sap is boiled in cans and kettles within the large wigwams, which stand from year to year, in which also they all sleep. They have a tradition that, before they could get iron kettles, their ancestors used to make kettles of clay in which they boiled the sap.

The smallest tree seen showing signs and scars of tapping for sap is less than five inches in diameter, and the largest nearly two feet. It seems that the tapping and scarring continues during the whole life of the tree, and some old trees are gnarled on all sides by the effort to overgrow the gashing they have suffered. The effect must be as if some malignant worm and all its progeny renewed its gnawing at the base of the tree every year.

The wigwams are the usual conical frame made of poles leaning together at the top and spreading to the ground all round, and covered with birch bark or cedar bark, there being only one opening for entrance and egress on one side. The smoke from the central fire escapes at the top among the loosely fastened poles.

*The western part of this area, comprising the Grand Portage Indian reservation, was subdivided by the United States government only in 1893, and no examination has been made of the most of it.

† This Portage was declared by the Webster-Ashburton treaty of 1842, to be "free and open to the use of citizens and subjects of both countries." Compare vol. 1, p. 112.

obstructed by brush and fallen trees. It follows an easy grade, except near Grand Portage village, and is not obstructed by rocky outcrops, although at several places it passes over bare ledges of the Grand Portage graywacke, and near the lake it intersects some of the lower slates. Near the route, however, rise hills several hundred feet, as already mentioned, and as represented on plate 85.

From Grand Portage it follows the main creek about a mile and a half, when it leaves the valley of the creek and continues more nearly in a right line in a northwesterly course. At three miles on the trail, at the crossing of a creek (Poplar river) that runs northeastward into Pigeon river, the valley of the creek is cut about fifty feet into the non-terraced deposits of the plain. The trail is here 498 feet above the lake, at a point half a mile south of this crossing, the ascent being gradual all the way over a smooth glacial deposit of till, this deposit having determined the location of the portage trail. Before reaching the highest point (sec. 32, T. 64–6 E.), there is a level tract of half a mile of red glacier clay, good land, once heavily timbered. Passing the notch in the hill range, the trail soon descends about seventy feet to this creek, and to the glacier plain, which is here a mile wide, and rises toward the northwest. The glacier movement was toward the west and southwest,* and must have covered and obstructed the lower portion of the valley of Pigeon river. The trail follows this plain, and soon rises, to the west of the creek crossing, to the summit of the portage, 743 feet above the lake, or 1,345 above the sea, at a point about five miles from Grand Portage village, sec. 26, T. 64–5 E. This is still a clay-covered plain, rising nearly as high as the dike hills further south, but enclosed by hills of the same structure that rise two or three hundred feet still higher.

The rock, *Grand Portage graywacke*, that is exposed along the trail (No. 295), is of a harsh, non-crystalline, scarcely slaty sort, grayish-green, and rather soft, and at half a mile from the west end of the trail it contains some white siliceous pebbles. At a mile and a quarter from Pigeon river is a low bluff of trap over which the trail passes. This is of the prevailing gray, compact sort. The bluff rises about three feet, and faces about north, running parallel with the hill ranges. The slate reappears but a short distance further east.

At Abita, or half way, gray slate appears plentifully on the trail, in loose pieces, and is seen *in situ*, a short distance further southeast. At one-eighth of a mile further south are two low trap ridges seen on the west side, rising from two to four feet above the road. This is near the town line between T. 64–5 E. and T. 64–6 E. In the N. E. ¼ sec. 31, just south of the crossing of Poplar river, the trail passes a notch in the hills. The hill on the west side of the trail, south of the creek, rises 355 feet above the creek, or 822 feet above lake Superior, and consists of trap rock; thence south-

*Compare the chapter on Carlton county; also F. B. TAYLOR. *Am. Geol.* vol. xx, p. 111, 1897; A. H. ELFTMAN, *Am. Geol.* xxi, p. 104. In 1898 glacial striæ were noted, sec. 27, T. 64-5 E., running 75° W. of S. true meridian.

ward the trail occasionally passes over only slates similar to those seen at Grand Portage village. The hill on the east side of the notch is similar to that on the west side, but was not measured.

*Geological structure.** The geological history of this little tract, so far as known at present from our field and laboratory studies, is about as follows, beginning at the bottom:

1. The Animikie strata were formed. On the area included within this plate only two of those parts of the Animikie that prevail further west are known, viz.: the fissile black slates and the quartzyte, but there is, in addition, above the Wauswaugoning quartzyte, the imperfectly slaty, greenish gray member, or Grand Portage graywacke (Nos. 295, 772W and 1835).

2. Surface eruptives and flows of basic rock, probably of minor importance. These are seen on some of the Lucille islands, where they seem to lie on the upper portions of the Animikie, cut by the great dikes of the country (No. 1847).

3. Epoch of profound igneous intrusion (Cabotian) forming the most of the dikes and sills of gabbro that penetrate the Animikie. This event probably cannot be definitely separated from the last. The rocks of these two epochs doubtless run together in other places, especially where the ancient surface is preserved. But throughout this area the denudation has been so profound that, so far as known, they are entirely distinct at the present surface, and the later date of the dikes seems to be plain (Nos. 282, 1849). This great gabbro invasion gave origin to the red rocks of the region and their variations by contact fusion of the sedimentaries (Nos. 285, 1845, 1853, etc.)

4. Erosion interval. Commencement of the Keweenawan clastic rocks (or Potsdam). Conglomerate (Nos. 254, 1831, 1832), quartzyte and sandstone (No. 256) of Potsdam age.

5. Eruptions (Nos. 255, 1834) more or less cotemporary with the fragmentals of No. 4, and very copious after the completion of the quartzyte, forming surface flows. Grand Portage island (Manitou).

6. Dikes later than No. 5. So far as known the eruptives of No. 5 and No. 6 were only basic, mainly diabase, with amygdaloidal diabase. The dikes of No. 6 cut the surface flows of No. 5 on Grand Portage island (No. 541).

The accompanying plate exhibits the areas of these rocks so far as is possible from the data now at hand. There is, however, no way of separating geograph-

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*The data from which this chapter is compiled are from the following sources:

N. H. WINCHELL. *Ninth Annual Report*, pp. 57-73; *Tenth Annual Report*, pp. 43-49; *Seventh Annual Report*, pp. 10-21; unpublished field notes made in 1893 and in 1896.

C. W. HALL. *Seventh Annual Report*, p. 26, 1878.

A. WINCHELL. *Sixteenth Annual Report*, pp. 288-292.

Compare, also, W. S. BAYLEY. On some peculiarly spotted rocks from Pigeon point, Minnesota. *Am. Jour. Sci.* (3), xxxv, pp. 388-393, 1888; Ibid., p. 54, 1889. The eruptive and sedimentary rocks of Pigeon point, and their contact phenomena. *Bulletin 109, U. S. Geol. Sur.*, 1893.

J. G. NORWOOD and RICHARD OWEN. In the report of David Dale Owen on the *Geological Survey of Wisconsin, Iowa and Minnesota* (1852), pp. 388-410.

FOSTER and WHITNEY. *Report on the Lake Superior Land District*, part ii, p. 12, 1851.

THOMAS CLARK. Report of Hanchett and Clark, 1865, pp. 47-53.

ically the later Keweenawan surface eruptives (the Manitou) from those of the Cabotian. They were each cut by a series of basic dikes, and these dikes in each case probably reached the surface and caused surface lavas. The Manitou dikes, though later, may have cut, and doubtless did in many places, the earlier Cabotian rocks, and they would now exhibit phenomena within those rocks that could not be distinguished from the true Cabotian dikes. Therefore, lacking an exact knowledge of the western portion of this area, the writer is unable to vouch for the Cabotian age of the rocks found there. It may be that the Manitou series, represented unmistakably on Grand Portage island, continues further west than the west point of Grand Portage bay, and it may be that the entire hill range, as already intimated, running southwestward toward Cannon Ball bay from the hilly region west of Grand Portage bay, is composed of Manitou basic rocks. That would be in keeping with the aspect of the basic dikes that cut the red rocks at the "eastern palisades" and Red Rock point. It will be by following carefully across the country the conglomerate and sandstone seen at the base of Grand Portage island, that the fragmental beds of the base of the Manitou can be mapped separately from the Cabotian. There will be more difficulty in separately mapping the Manitou igneous rocks, since they may have penetrated the same strata as the Cabotian intrusives.

The fissile slates of the Animikie appear in the hills northeast from the head of Wauswaugoning bay, and in the gorge of the Pigeon river below the Partridge falls, and especially below the Grand Portage landing. These slates are rather more siliceous and less carbonaceous than the black slates of the Animikie described by Dr. Grant at Gunflint lake, and it is not at all certain that they do not represent simply one of the phases of the slaty quartzyte of the upper member. The carbonaceous black slate proper of the Animikie has been supposed to cross the international boundary and enter Canada in an east-northeast direction in the vicinity of Rose (or Mud) lake, which would rather exclude it at the Partridge falls. At the same time, if the dip of the quartzytes seen along the lake shore of Pigeon point be continued toward the north without faulting, it would carry the Wauswaugoning quartzyte sufficiently high to expose the black slates at Partridge falls. It is apparently the same thin slates that appear in the talus of the hill on the Canadian side at the south end of South Fowl lake (No. 299). The transitions from one portion of the Animikie to the other are so gradual, with recurring alternations of the lithology of the former within the latter, that any individual outcrop might fall in the bottom of the quartzyte, or near the top of the black slates.

The rock at Partridge falls (No. 771W) is a rather fissile, yet siliceous, hard slate, grayish to greenish, varying to fine grained. It is finely ripple-marked, dips south from 12° to 15°. Dr. A. Winchell called these falls "the Minnehaha of the boundary," and gave a careful description with diagram, as below.

"The following diagram shows the more important facts. The highest rock, A, slopes upward at such angle that if continued to the standing place, D, close to the falls, it would be ten feet above it. A dike of gabbro,

which seems to be of the same character as the gabbro of the country, intersects the formation between the two falls, and is about forty-five feet wide. If this proves to be the same as the ordinary gabbro, it would seem probable that it was of cotemporaneous intrusion, and that this was one of the fissures from which the flow came which inundated the country. Further, as no gabbro appears on the surface in the vicinity, there is evidence of much erosion of gabbro. And still further, if one gabbro vent of small dimensions existed, not unlikely the whole escape of the outflow was through numerous vents of moderate capacity, rather than one or two great fissures." —*A. Winchell, 1887.*

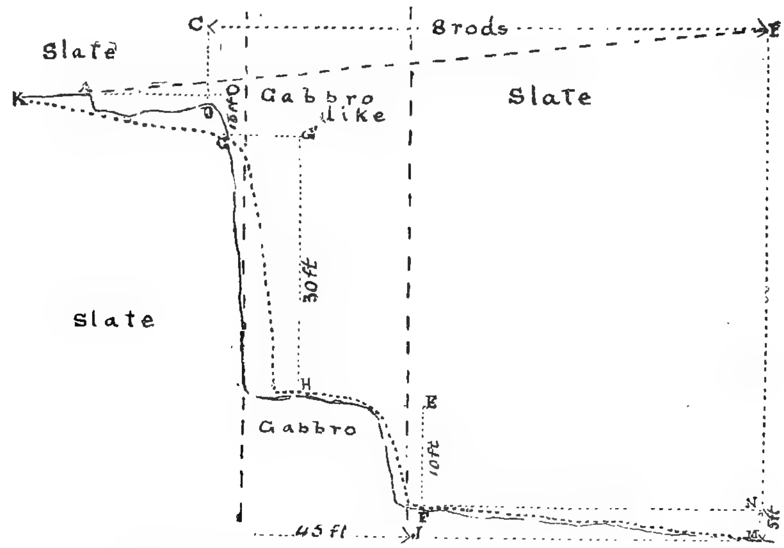

FIG. 93. DIAGRAM OF PARTRIDGE FALLS IN PIGEON RIVER.

The measurements given are estimated. The diagram is not drawn to a scale.

A—The highest rock above the falls.
B—The hight at which it reached at the foot of the descent.
C B—Eight rods, distance from brink of falls to foot of rapids.
D—Standing rock at brink of falls.
E F—Ten feet, hight of lower falls.
G H—Thirty feet, hight of upper falls.
I J—Width of dike of gabbro, forty-five feet.
K G—Rapids above the falls. Descent, O G., twenty feet.
F M—Rapids below the falls. Descent, M N., five feet.
K G H F M—Surface of water.

The brink of the Partridge falls is also represented by figure 3, plate PP.

Pigeon river falls. The falls of Pigeon river are shown by sketch on following page (figure 95), which is a reduced copy of a sketch made by Richard Owen, in 184(8?). Their present appearance is shown by the half-tone from a photograph made in 1877 (figure 1, plate PP). A similar view is presented by Prof. W. S. Bayley, in plate 1, of bulletin 109, of the publications of the U. S. Geol. Survey, taken probably in 1888. At the falls the Animikie slates are cut by two gabbro dikes, which form an angle with each other, as shown by the following figure (figure 94). The slates at the falls, according to Bayley, show alteration toward the red rock similar to that exhibited widely on Pigeon point, and described below. These dikes appear to converge toward a hill of gabbro (No. 261), which likewise appears in the midst of the slates a short distance to the southwest from the falls. The gorge below the falls is shown by plate PP, figure 4, looking down stream.

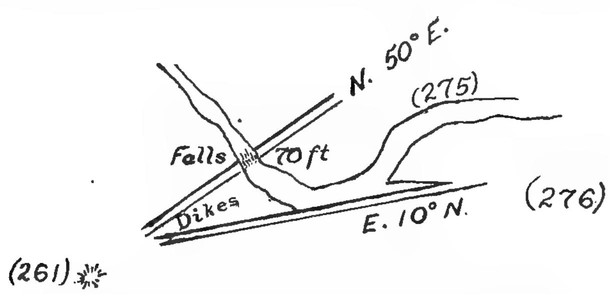

FIG. 94. DIKES CUTTING SLATE AT PIGEON RIVER FALLS.

The Wauswaugoning quartzyte, however, when fully established, presents rather marked and persistent characters. It is essentially a granular quartzyte, but embraces some feldspathic grains. Its typical outcrops are at the head of Wauswaugoning bay and thence eastward through the whole length of Pigeon Point peninsula. It is easily

affected by the basic intrusives and converted into the "red rock" of the region. This may be seen in ascending mount Josephine, and near the bay on the east side of mount Josephine. This rock is represented by samples Nos. 265B, 553, 1837, 1838. Its normal color is gray, but on weathering, and especially when it is metamorphosed by contact with the dikes of the region, it is purplish and red. In this respect it takes a conspicuous part in the production of quartz porphyries and red granite. It passes through various stages which have been fully investigated and illustrated by W. S. Bayley,* and which are described in connection with the petrographic characters of various rocks in volume v, viz.: rocks Nos. 285, 292, 1822, 1834C, 1839, 1840, 1841A, 1842, 1844, 1845, 1850, 1852, 1853. The fact, in general, of such fusion and recrystallization of the sedimentary rocks was announced earlier, for the region of northeastern Minnesota, by J. G. Norwood† and by the writer‡, but the microscopic details and the mineralogical alterations were first fully presented by Dr. Bayley.

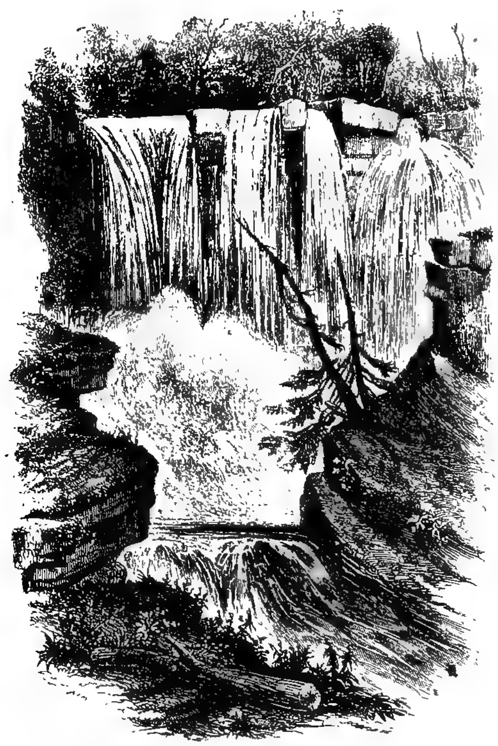

FIG. 95. PIGEON FALLS (AFTER OWEN, 1848).

Along the south side of Pigeon point this quartzyte is frequently the barrier to the lake, rising in a gently sloping platform from the lake to the hight of ten to twenty or thirty feet, and occasionally to 150 feet, then breaking off perpendicularly toward the north in a manner characteristic of the Animikie. It is often finely or

* *Bulletin cix, U. S. Geol. Survey.*

† *Report on the Geology of Wisconsin, Iowa and Minnesota.* By D. D. Owen, pp. 405, 408, 418.

‡ Typical thin sections of the rocks of the Cupriferous series in Minnesota. *Proc. Am. Assc. Adv. Sci.*, vol. xxx, pp. 160-166, 1881; *Ninth Annual Report* (1880) p. 70; *Tenth Report*, pp. 57, 59.

coarsely basaltic in angular columns. It gives place frequently to the igneous rocks, especially at the sharp points that enclose the bays; and along the north it is variously altered, through more and more recrystallization, or was fused and then flowed as a red felsyte and quartz porphyry, which can be traced almost continuously from Wauswaugoning bay to near the extremity of the point, or cooled slowly and formed red granite (Nos. 292 and 1853).

The Grand Portage graywacke. The rock that appears occasionally on the Grand Portage trail has received this name. Its best outcrop within the area of this plate is at the northwestern end of the trail, where it occupies the highest points on the trail (rocks Nos. 295, 772W). It is seen occasionally along the immediate trail further south and is known more widely further northwest, where it spreads over the low flat land of the Puckwunge valley and the drift-covered plains. It barely exists in the upper portion of the Animikie at Grand Portage village, appearing in the top of the hill in the S. W. ¼ sec. 9, T. 64–6 E. This hill rises about 250 feet above the lake. It consists primarily of siliceous Animikie slate. It is crossed by seven dikes, the western ones, which stand up isolated and are cross-columnar, running about east and west, and the eastern about northeast and southwest. Some of them enclose detached portions of the slate, which there is hardened and "baked," but not reddened, so far as seen. On the other hand, in some of the slates of this hill small light-colored spots appear as incipient metamorphism, after the fashion of the round spots in some red slate and shale of Pigeon point. The most easterly of the dikes forms the crest of the hill. It is about fifty feet wide and only differs, so far as can be seen, from the mountain dikes of the region in being smaller. It has vertical walls of trap at the summit. The top of the slates of the hill is of hardened quartzyte. The graywacke rock is represented by Nos. 1835 and 1836. The usual slate of the hill is represented by No. 252, which appears at the beach. This rock is here cut by a dike thirty-nine feet wide, running E. 15° S. The slate here has septariæ several feet wide, round which the slates are disturbed and warped. The dip is here S. 5°.

The Grand Portage graywacke is a rather soft siliceous graywacke of a grayish-green color, lying in beds from two to six inches thick, breaking in a somewhat rough and conchoidal, coarse fracture. In thin section, while the clastic quartz grains are apparent by their rounded outlines, they are uniformly enlarged by secondary increments so as to have angular interlocking projections. They are associated with a few fragments of striated feldspar, and with much indeterminable debris, much of which is opaque. In some instances it is seen to sparkle on a fractured edge with reflected light. Such reflecting surfaces are due to the formation of calcite crystals embracing the other grains poikilitically. It contains a considerable ferro-magnesian ingredient, though the specific minerals are altered and lost.

This rock probably has been worn away from the great dikes of the region in their upper protruding portions. It is plain that the dikes must originally have been enclosed in fissures in some rock in order to have acquired their vertical walls, and as they are believed to have been injected after the close of the Animikie, and before the formation of the Puckwunge conglomerate seen at the base of Grand Portage island, there is no other series of strata that could have filled the interval which is now expressed by the protruding vertical dikes. This soft and coarsely slaty graywacke therefore seems to have a thickness of at least two hundred feet.

The basic Cabotian rocks. What was the latest rock formed and whether it was yet below the ocean's water at the time of the close of the Animikie, when the gabbro revolution occurred, is not certainly known, and the subsequent denudation has been so great that it will be very difficult to find it, and identify it. We only know now that the great dikes protrude up through the Animikie, and that their surface representatives are voluminous in the form of diabases and amygdaloids, and perhaps as volcanic debris, represented by the Grand Portage graywacke. Some of these surface rocks are also rhyolytes and quartz porphyries, the product of fusion of the contacting sedimentaries.

The highest land and the largest dikes are found in the northern part of this area, rising from 1,500 to 1,600 feet above the sea.* They form abrupt elevations, perpendicular near the summit on both sides, which run for two or three miles or or cease after extending less than a quarter of a mile. They run prevailingly east and west, varying to northeast, and sometimes reach a width of 500 feet or more. To this statement the dike that forms mount Josephine is a noteworthy exception, as it extends at right angles to the normal and usual direction, and at the same time is one of the larger dikes of the region. Of this more careful study has been made.

Mount Josephine (figure 96) has a hight of 1305 feet, and its perpendicular, east-facing wall, above the slates, as viewed from Wauswaugoning bay, has an imposing and almost threatening aspect. At the very toe of mount Josephine (Hat point) the gabbro has a marked gneissic structure, sloping steeply northward, the lake having acted on it from the south so as to break it away and bring out a jagged or dragon-tooth outline (figure 97). This is in marked contrast with the southerly dip of the slates and traps of the region. The water laves the dike only for about one-third the distance from Hat point to the head of Wauswaugoning bay, and then slates form the shore, without much interruption, dipping strongly toward the southwest, to two-thirds of the distance to the head of the bay. The last third is occupied by drift, or by slaty quartzyte somewhat modified (No. 1837). The slates are cut, between the point and the head of the bay, by eleven diabase dikes which appear on the eastern escarpment, running about perpendicular to the main dike, and may be presumed to be apophyses from it. They vary from three to seventy feet in width. Several other similar dikes are seen crossing the quartzyte and slates at the head of Wauswaugoning bay, hardening and reddening them. They rise irregularly from the water, form jagged, low hills, and in the openings of their joints is seen quartz porphyry in seams and patches (Nos. 1838, 1839).

The ascent of mount Josephine is most feasible from the west side, following a portage trail which crosses the base of the peninsula leading to Wauswaugoning bay. At the point where this trail crosses the peninsula the hight is 1,038 feet, and the surface is terrace-like and flat. This terrace may be followed northward to a point opposite the south end of mount Josephine, from which a steep ascent may be made to the cap. At about 100 feet above the terrace a metamorphic quartzyte is encountered (No. 1827). It is brecciated and again compressed, no gabbro being visible. This rock, in thin section, is seen to consist principally of quartz grains with irregular

* These dikes are not accurately represented on the plate. They suffer much more interruption than is represented, and are sometimes branched and broken.

contours, interlocking with each other and with the scant reddish feldspar, and also grown into the latter in the "Eozoon" structure. It is a recrystallized condition of the quartzyte. At other places near, both above and below, a rather fine-grained condition of the gabbro is mingled with this rock in irregular patches (No. 1828). It is olivinitic and has an ophitic structure, being hence a diabase. Rock No. 258 is from the Hat Point dike on the east side, 150 feet above the water, and is one of the few instances in which the rocks of this great intrusion have been found to show an *ophitic relation between the feldspars and the olivines.* At the summit is a small area which has an elevation, according to the U. S. Lake Survey, a little over 1,305 feet. The rock (No. 1829) is rather fine grained, and especially finer than that seen in the hills at Double bay. There are, however, some very coarse patches with feldspars three inches in longer dimension.

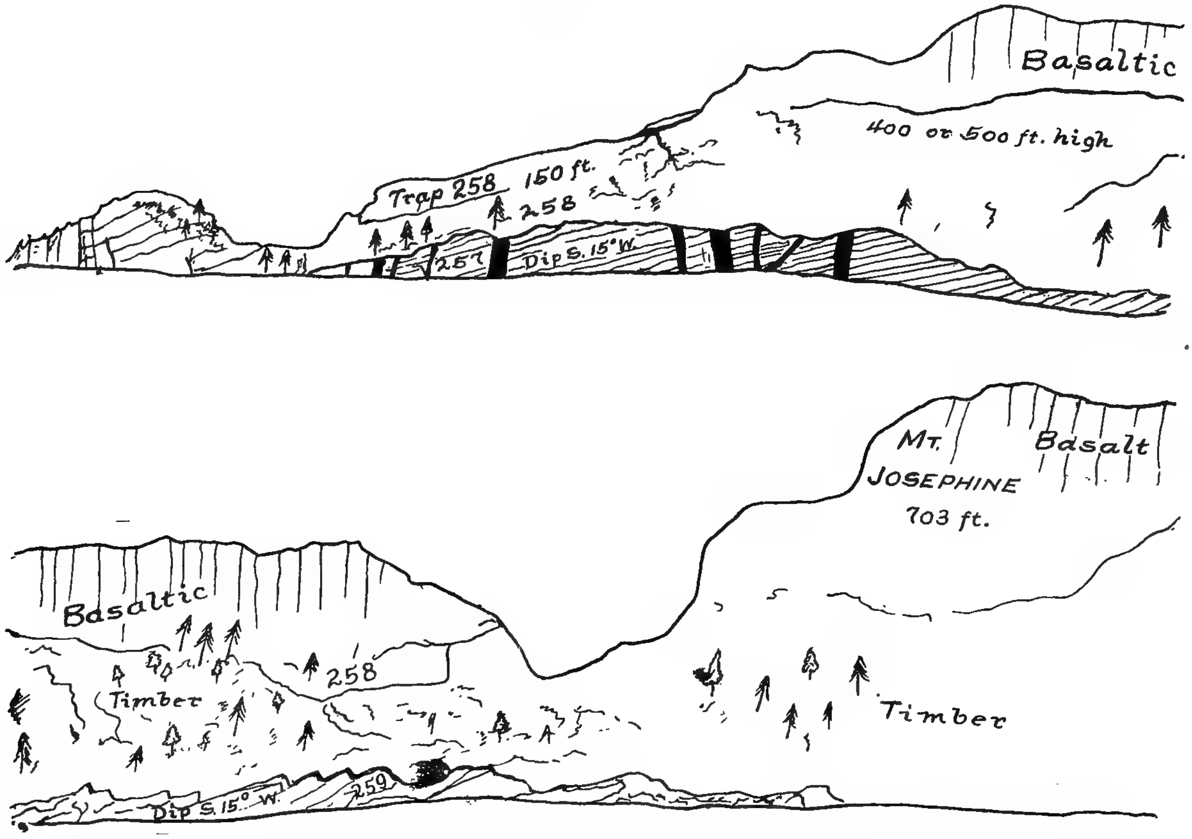

FIG. 96. PROFILE OF HAT POINT FROM THE EAST.

The top is a glaciated dome on which, however, the direction of glaciation could not be made out—a dike of enormous size. From it the dike-shapes of the other hills toward the north can be plainly discerned. These dikes make the mountains of the region. On one of the subordinate ranges toward the northwest can be seen patches of red rock, one (No. 1830) on the east side of the Grand Portage trail and one (No. 1834C) on the west side.

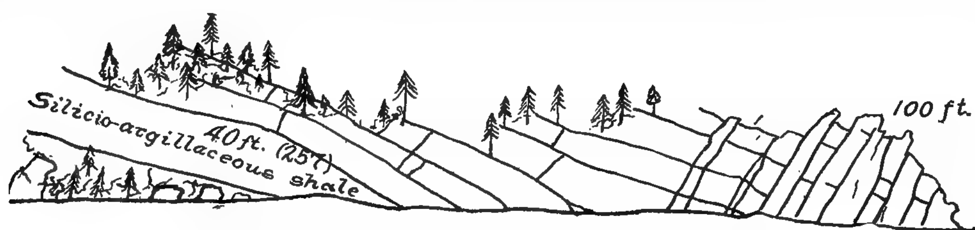

FIG. 97. EXTREMITY OF HAT POINT FROM THE WEST.

The smaller dikes, which run generally parallel with the larger ones, except some still smaller which seem to be perpendicular apophyses or belong to a later series, make hills of less altitude. Those that appear at the lake shore are from twenty to fifty or 100 feet wide. Each one occupies a fissure in the old formation due to some widespread crustal disturbance. Along these fissures were favorable opportunities for faulting in the Animikie. The fractures were prevailingly perpendicular to the bedding of the slates, and the smaller dikes exhibit a horizontal columnar structure, while, so far as observed, the large dikes do not show a strictly basaltic structure. These have a coarse jointage running parallel with the fissure, and another irregular jointage which

has a rough resemblance to bedding, and in the interior of the state may have been called bedding in many instances. This seems to take the place of the prismatic structure of the smaller dikes. It also slopes toward the lake uniformly and gives the dike the appearance, when viewed favorably on one end, of having a heavy-bedded structure; in other words, of a coarse flowage structure. It is quite reasonable to attribute to this fact the idea formerly prevalent that the gabbro, whether in the form of large dikes or sills, or constituting great masses, and without amygdaloid, is of the nature of a surface lava flow.

It would be an inevitable consequence that such dikes produced surface lavas; and a large area of the northeastern part of Minnesota is covered by such lavas. They lie to the south of the region of dikes and sills, and, for the most part, they occur visibly along the lake shore, where they constitute the Cabotian surface traps and amygdaloids, but which it is impossible as yet to separate satisfactorily from the traps of later date, *i. e.*, from the Manitou portion of the Keweenawan.

There is another interesting fact which must be considered. Many of the dikes about Grand Portage cut through earlier traps and amygdaloids and such dikes could not have been cotemporary with the dikes of Cabotian age. Excluding those surface traps that are certainly later than the base of the Puckwunge conglomerate, *i. e.*, later than the conglomerate at the base of Grand Portage island, there are surface amygdaloids whose date is uncertain, and others that probably preceded the Cabotian dikes and sills. At the west side of Grand Portage bay, at the lake shore, in sec. 20, T. 63-6 E., the shore is composed essentially of such amygdaloid. At points further west, the same or similar amygdaloidal traps form the most of the coast line, and they apparently lie below the red rock of the Eastern Palisades and Red Rock point (figure 98). These old traps, as well as the red rock, are cut by one or more series of later dikes, and sometimes these dikes are 100 feet in width (No. 1855),

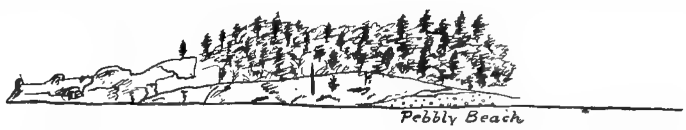

FIG. 98. RED ROCK POINT, FROM THREE-FOURTHS MILE EAST.

and have the direction and aspect, and apparently the age, of those that rise into mountain-like ridges further north; at least it is not possible, as yet, to distinguish them from the great dikes. Inasmuch as there is reason, geographically considered, to ally these amygdaloids west of Grand Portage bay with those later than the conglomerate of Grand Portage island, and since there is no apparent lithological difference, thus making them of Manitou date, they are provisionally placed in the Manitou, of a date later than the Cabotian dikes and sills, although the great dikes that penetrate them seem to be referable to the age of the Cabotian, and of the group that forms mount Josephine and the associated red rock, the debris of which is found in the Grand Portage island conglomerate. But those westward from Deronda bay are considered older, occupying an epoch of time when the premonitions of the great gabbro revolution were displayed in the form of volcanic ejecta which were spread over the surrounding regions in the form of lavas and perhaps of ash. They may be substantially the time equivalent of the Grand Portage graywacke.

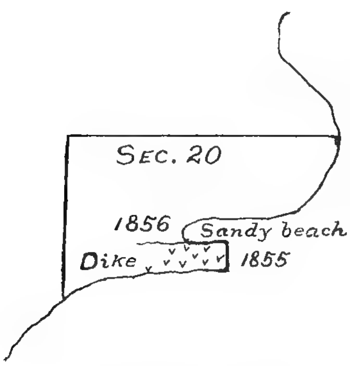

FIG. 99. DIKE CUTTING AMYGDALOID.

At the point above mentioned (sec. 20, T. 63-6 E.) the dike runs in the usual direction (figure 99) constituting the chief feature of the point, the little east-facing bay being due to the retreat of the coast line on the north side of the dike where the amygdaloid has been more easily and rapidly worn away by the friction of the coast. The softer rock (No. 1856) resembles some of the amygdaloid of the south side of Grand Portage island, and less some of the amygdaloid seen on the south side of the southeasterly island of the Lucille group. In much of its surface wall, facing north, it has quartz fillings, but in general the pittings of the weathered surface are due to the removal of calcite. The dike is about 100 feet wide, and is fine grained and dense at the contact with the amygdaloid, but toward the centre the feldspars are an inch and a half across.

Other basic dikes appear at the lake shore further west, cutting both these, or very similar trap and amygdaloidal beds, as well as the red rock at Red Rock point. In the bay east of Red Rock point is an interesting exhibition of these older amygdaloids. The network of dikes here has been described, and some of them illustrated by Norwood. The dikes are represented by Nos. 233, 234, 236 and 242; and the rock cut by them, by the Nos. 232, 235, 237, 238, 239, 240, 241, 1824, 1825 and 1826. These beds are curiously contorted and upheaved. Rock No. 237 forms

an isolated mound, standing between the beach and the lake. It is curvingly bedded and laminated, rising eighteen feet, and extends eighteen feet on the beach, shaped like a haystack, and has a reddish-brown color. Much of this rock is closely jointed and slaty, the slates curving about so as to visibly turn a right angle in thirty feet, *i. e.* with a chord of thirty feet from one radius extremity to the other. The curvature continues so as to make more than a right angle, and in some cases it goes back in exactly the opposite direction. It also shoots upward and crosswise; at the same time it is cut by joints at sharp angles, thus becoming erosible by the beach action. It has much the aspect of a contorted sedimentary rock. It has large dish and basin-shaped areas. The strata are from one-half to one inch thick. Where it is amygdaloidal the fillings are large and made in part of calcite and fluorite. But usually they are small and consist of agate (No. 1826A) with a green exterior, making them look like robins' eggs. This rock, and its western extension toward Red Rock point (rock No. 1823), in some of its aspects resembles the so-called Two Harbor rock, which is a glassy basalt, and it probably has an igneous origin. The thin sections show that it contains, in proportion of 25 to 50 per cent, undifferentiated magma which is continually dark or nearly dark between the nicols. In this lie the feldspar and other microlites. The narrow dikes, being firmer, run out into the shallow bay, forming low, long islands.

The only structural evidence that can be adduced going to show the pre-gabbro age of these old amygdaloids was met with on the islands of the Lucille group, which lie south of Pigeon point (plate GG). Magnet island, the most southeasterly, and probably High island, in part, consist of amygdaloid. The former has a hight of about thirty feet, and the grand structure seems to be that of a series of heavy trap beds, sloping south at an angle about 20°. At the east end the rock is highly amygdaloidal (No. 1847), with green fillings, but some (No. 1848) is massive. The latter has coarse pyroxenes entire, *i. e.*, of earlier generation than the feldspars, though embracing the olivines. It also contains considerable areas of magma-residuum, which now is converted to a greenish, nearly isotropic substance. Through these rocks runs a large dike of porphyritic gabbro (No. 1849), in which the feldspar crystals are large, and weather white, like huronite. This runs diagonally across the island, and is apparently the same that appears on the north side of Syenyte island, next west. That this dike is of the Cabotian age is indicated, though not proven, by the fact that it contains small transported masses of red rock (No. 1850) derived from contact with the sedimentaries in a manner similar to those seen on mount Josephine. That the amygdaloid cut by it is of pre-gabbro age is indicated, though not proven, by the close proximity of the Animikie slates and the general environment. If this amygdaloid be not of pre-gabbro age, the Grand Portage conglomerate must intervene between Magnet island and Syenyte island, which is highly improbable.

Again, on High island, similar surface eruptives are very nearly superposed on Animikie slates; at least, there is a more or less bedded condition of igneous rock, while in part the island consists of slates. However, the knowledge we have of that island will not warrant the assertion that any of this bedded igneous rock is amygdaloidal. It may be of the nature of a sill between the Animikie strata directly connected with the main dike of the island.

Therefore, although the evidence is not conclusive, it will warrant the hypothesis that these surface eruptives are closely connected with the Animikie, and this hypothesis has to be extended to cover the similar rocks westward from Deronda bay.

The red rock rises in an isolated knob near Little Portage bay to the hight of over 150 feet, is found in streaks and patches, as represented on the plate (No. 85), to a point northwest from Grand Portage village, where it occurs as a portion of the southward-facing wall of one of the great dikes (No. 1834C). It is in general found in immediate contact on the basic rock of some of these dikes, or is closely associated. However, the eastern palisades, which consist of this rock, appearing on the beach a short distance west of Red Rock creek, are not known to be so closely connected with the basic rock, and are more likely to be a portion of a large surface lava flow, and, as such, it may be supposed to continue westward to the main area of this red formation to the west from the area of this plate. This is, however, largely a matter of conjecture, for there is no knowledge of it in the banks of the Mawskiquawndu river, which flows across the area which it is presumed to occupy. Throughout the valley of this river the water runs, according to Prof. C. W. Hall, wholly on drift materials. At the eastern palisades the quartz porphyry (No. 620) rises abruptly from the water to the hight of about thirty feet, breaking off square and suddenly on the land side. The rock extends but a short distance in the beach, perhaps 150 feet, with a dip toward the southeast. There are slight exposures of the same kind of rock a few rods further west, and still further west are basic trap exposures in the beach which appear to pass below the red rock. Back from the shore this rock can be traced in a tolerably level plain, according to Norwood, to the first high dike.

At Red Rock point the same rock reappears, but dips south-southwest. It is here cut by several dark-colored basic dikes, and, on the east of the point, it rises in a perpendicular wall. A little further east, along the beach, the succession of outcrops is such, united with the dip, that it is apparent that the same horizon as on the west of the eastern palisades appears again. Here there is apparently a lithological transition to more and more basic rock in passing toward the east, as represented by the rocks Nos. 1822, 1823, 1824. It seems probable, therefore, that the red rock that appears on the shore at the eastern palisades is a surface lava flow lying between two basic flows.

Two of the Lucille islands consist essentially of this rock, and it was struck in the bottom of the mining shaft on Governor's island, where the vein which was the cause of the exploration seems to have entered red granite, showing the origin of the fissure to be later than the Cabotian. This is an inference from the existence of large calcite masses carrying bornite adherent on fresh granite fragments which came from the bottom of the shaft (No. 1853). There are also pieces of fine-grained red rock enclosed in the porphyritic diabase, which cuts diagonally across Magnet island.

Syenyte island consists largely of quartz-porphyry. Seven east-west dikes cross the red rock, varying in width from three to forty feet, the northernmost and highest being the porphyry dike (No. 1849) seen to cross Magnet island.

At the old mining station of the Lake Superior Copper and Silver Mining company on Governor's island, just north of Little Brick island, an observation can be made as to what becomes of the black slates when subjected to the influences that fuse and then form granite and quartz-porphyry from the quartzyte of the region. In general they are known to become dense and hard, with much jointing. But here, near the boiler house, is a dike running east and west through the slates. This dike is only ten or twelve feet wide, but in some places the adjacent slates are not only hardened, but on weathering they turn grayish-red or pinkish, and in one angular projection on which the heat of the dike may be supposed to have acted more effectively, there are seen developed some red orthoclase crystals which are scattered through the dense matrix like those of a porphyry (No. 1854). This is a step toward showing that the black slates, although much less amenable to the alteration, can be made to take the crystalline condition by contact with heated basic intrusives, and also that they could be made to assume the condition of red granite and of quartz-porphyry.

The quartzyte shows its easy transition to a crystalline condition on the east side of mount Josephine, as already stated. There could be no plainer ocular demonstration of the origin of this rock from the sedimentaries than can be obtained by a brief review of the relations of the basic and the acid rocks here exhibited. The porphyry (No. 1839) appears in patches in the quartzyte. This is not only crystalline, but in addition has distinct larger crystals of orthoclase and somewhat rounded crystals of quartz. It has been so nearly molten that it has entered cracks in the parent rock, which was less plastic. In some places the parent rock is spotted with red and green (No. 1840), and at a point a little further up the hill, toward the northeast, along by a branch dike that comes across the quartzyte from the mother dike further north, the quartzyte is largely porphyritic, and then weathers a bright red color. There can be seen all the stages of transition in the various parts of these

hills, and in some cases there is, within a few inches, a visible change from fragmental through hardened quartzyte to sub-crystalline rock and to quartz-porphyry. In other cases it appears that quartz-porphyry is formed in strings not more than half an inch wide, running through the gray quartzyte. Again, it occurs in blotches of irregular form, usually elongated with the main structure; or it seems again to be like nodules, and in the centre of the nodules may be larger amounts of quartz. A similar series of changes in the slates and quartzytes of the region can be traced at Little Portage bay, some of the clastic rock becoming wholly recrystallized and converted, toward the north, to gneiss and to "red rock," which cannot be separated from the series seen in the little hill which rises about 150 feet, at almost half a mile west of the bay, the whole being due to the heat generated by the great gabbro dike which forms the axis of Pigeon Point peninsula. The position of these rocks (described in vol. v) is shown by figure 100.

FIG 100. LITTLE PORTAGE BAY, PIGEON POINT.

The carbonaceous slates that exist at a lower horizon in the Animikie have given a characteristic manifestation, in connection with this metamorphosis, in the formation of considerable deposits of graphite, which formerly attracted attention for its prospective economical value. This occurs on Pigeon point (Nos. 270, 271, 1841), S. W. ¼ sec. 32, T. 64–7 E. The rock here is quite quartzose, but apparently with secondary quartz, and is charged with graphite in the form of nodules from the size a pin head to one-half or three-fourths of an inch in diameter. Some pieces are two or three inches across, and in the working (for silver) in the shaft sunk here some were found more than a foot in diameter, usually in flat and irregularly shaped slabs. The phenomena here, and the mineral associations, as well as the geological environment, are all similar to those at Silver islet, near Thunder bay.

The Puckwunge conglomerate. There was a cessation of the igneous disturbances which characterized the Cabotian revolution, but the agitation of the ocean was continued and violent. During this resting-period of the volcanic forces there was formed an important series of fragmental strata the base of which is this conglomerate. Within the area of this plate it is known only at the base of Grand Portage island, but it seems to extend, in connection with its overlying sandstones, across the Indian reservation northwestwardly to the hills on the south side of the Puck-

wunge valley,* where its stratigraphic position is indicated, and its appearance is described in another chapter (plate 69). At Grand Portage island it leaves the coast, reappearing on Isle Royale, where it is above a lot of basic eruptives (No. 560), and has a considerable thickness of red sandstone and red shale above it, but in places is separated from the sandstone by a series of basic lavas.† The rocks of Grand Portage island have been thus summarily described:

> The lowest beds exposed are at the northeast corner of the island; they consist of coarse and fine-grained sandstones, and arenaceous slates. They are cut and overlain by sheets of basic igneous rocks (at least a considerable part of which are effusive), which dip in entire conformity with the underlying clastics. The lowest exposed layers of the sandstone are decidedly conglomeratic, the foreign pieces often being several inches across. These conglomerate beds are composed largely of fragments of quartz, gray and reddish quartzyte, siliceous slate, a dark, flinty rock, red quartz-porphyry, and red granite. Most of these, more especially the quartz pebbles which make up the bulk of the rock, are clearly water-worn and well rounded. The quartzyte and slate pieces are similar to those occurring just to the north and northeast in the Animikie series, and the same can be said of the quartz-porphyry and granitic pebbles. In fact all the pebbles of the conglomerate can be matched in the Animikie strata near by. The red quartz-porphyry and the granite have been shown, at least in their present condition, to be later than the Animikie,‡ and rocks of this nature which could have furnished the pebbles in the conglomerate under discussion do not seem to be known in this region, except in the Animikie and later series. Moreover, the alteration and recrystallization of the Animikie sandstones, pebbles referable to which occur in the conglomerate, date from the same time as the quartz-porphyry and granite. In addition to the fact that the pebbles of the conglomerate can be referred to the Animikie rocks close at hand much better than to any others, is the fact that the sandstone and conglomerate of Grand Portage island do not show evidence of having been subjected to metamorphosing forces, as do the sandstones of the Animikie in the immediate vicinity.§

Above the conglomerate is not much sandstone visible on the island (perhaps ten feet), and the conglomerate shows a total thickness of about twenty feet, the whole dipping S. 10° E. at an angle of 8° or 10°. The conglomerate is shown by rocks Nos. 254, 549, 1831; the sandstone by Nos. 256, 546, 548, 1832, 2074; the surface lavas, cotemporary with the fragmental accumulation, by Nos. 255, 542, 543, 544, 545, 547, 1833, 2075, 2076, and by the most of the rocks of the higher part of the island (Nos. 544, 1834), and the dike rocks by Nos. 541, 550, 551. These are fully described in another place. It is sufficient to add to the statements already made, as to the nature of these fragmental strata, that in some thin sections of the darker portions of the sandstones can be seen fragmental devitrified glass grains, and evidences of tuffaceous accumulations, indicating cotemporary volcanic action. The bottom of the lava flow (No. 1833) contains fragments showing a flow structure, itself containing considerable basaltic glass and being very fine grained. The quartzyte seems to have accumulated very readily between the eruptions, and rapidly resumed its prevalent character, although the very lowest portion of a layer is unusually dark colored from abundance of the basic debris (No. 2074). At the top of the quartzyte layer (No. 2077) there is apparent but little effect of the overlying trap sheet visible in the quartzyte. It is slightly baked and hardened. In some cases a thin, distinct quartzyte mass,

* N. H. WINCHELL. Some new features in the Geology of Northeastern Minnesota. *Amer. Geol.*, vol. xx, p. 41, 1897.

† Dr. U. S. Grant called attention to the significance and importance of this conglomerate on Grand Portage island. *Amer. Geol.*, vol. xiii, p. 437, 1894.

‡ W. S. BAYLEY. The eruptive and sedimentary rocks on Pigeon point, Minnesota, and their contact phenomena. *U. S. Geol. Survey, Bulletin No. 109*, 1892.

§ U. S. GRANT. *Op. cit.*

lenticular in form, is wedged into a space between or within the eruptive sheets. The cement of the quartzyte, as well as of the conglomerate, is sometimes very largely calcite, evidently derived from the eruptives, and this also is the filling in most of the amygdaloid.

The data connecting this conglomerate with the outcrops in the Puckwunge valley cannot be said to be sufficient nor wholly reliable. No intervening outcrop has been seen by any member of the survey. One of the employés,* however, being sent to a large hill southwest from Grand Portage village, distant about two miles, reported that the hill was composed mainly of sandstone, and he brought small samples of the rock to illustrate it. These samples were as follows, but owing to the information being at second hand they were not preserved:

At the elevation of about 350 feet above the lake, an outcrop appears of a light-colored rock, on the face of the mountain, with a cap of basaltic rock evidently forming the summit. This can be distinguished with a field-glass from Grand Portage island. (1) The bottom of this outcrop consists of brown and reddish sandstone, and this rises to a thickness of forty or fifty feet. (2) Coarse, more arenaceous, white sandstone, fifty to seventy-five feet. (3) Dense, dark-green amygdaloid (?), resembling No. 1833, thickness unknown. This has some foreign grains, viz.: red jasper, etc. (4) Coarser amygdaloid, embraced apparently as a foreign piece in a finer grit, thickness unknown. (5) Gabbro trap, of the usual variety, forming the top of the hill, thickness fifty feet, more or less. Owing to the source of the evidence, and the supposition that this fragmental rock probably represented some part of the Wauswaugoning quartzyte, no further attention was given to this report. Its importance is made apparent on reviewing the structural geology on a broad scale, since it is likely to represent the strike of the base of the fragmental Keweenawan from the Puckwunge valley to Grand Portage island.

Note.—This was afterwards examined by Mr. Elftman, who identified it as the Puckwunge conglomerate. See the chapter on *Structural Geology*, vol. v.†

The Manitou. So far as can be definitely affirmed, therefore, the only Manitou traps that occur within the area of this plate are those that lie on the sandstone of of Grand Portage island, and near Grand Portage village, or are interbedded with them as surface flows, or cut them as later dikes. They have already been enumerated by their field members. What portion, if any, of the trap and amygdaloid which occupy the coast west from Grand Portage bay belong to the Manitou, it is at present impossible to state. Structural considerations would lead to the belief that the point next west to Grand Portage bay is of the same age as Grand Portage island, and that the foregoing sandstone strata, reported by Pireau, are the equivalent of those seen on Grand Portage island, or at least that these traps fall into the Manitou. If this be the fact, (which it is hoped may be investigated before this chapter is published), then considerably more of the traps along the coast further west would inevitably also fall into the Manitou series, continuing as far west at least as the east side of Deronda bay, and the accompanying map (plate 85) is so constructed.

At present, therefore, it is assumed, in order to provisionally adjust the facts into a reasonable structural sequence, that there were three series of basic surface traps, viz.:

1. That which preceded the great gabbro dikes and sills, and is closely superposed on the Animikie, and perhaps interbedded with its upper part.

2. That which was cotemporary with, and resulted from, the great basic dikes of the region. These would be superposed on the last, and it would be impossible to separate them geographically or structurally. This is the eruptive epoch called

* Frank Pireau.
† The reader will also find a description of the Puckwunge conglomerate in the *Twenty-fourth Annual Report*, p. 34.

Cabotian. It is probable that all the red rock of the region, if not of the state, was formed at this time. Some of it cooled slowly, forming granite, and some was extruded as quartz porphyry, and some formed amygdaloidal lavas.

3. The Manitou traps that accompany the conglomerate and sandstone of Grand Portage island, separated from the foregoing by the Puckwunge conglomerate.

Conformably with this scheme it is necessary to place all the dikes, at least those that can be allied to the mount Josephine type and date, in the Cabotian, and probably a great many of the smaller ones. It is also necessary to recognize the fact that later dikes cut the Manitou traps of Grand Portage island, and that hence there is another series; it is not improbable that dikes of this date were quite frequent, and it must be admitted that some are seen cutting not only the traps of the mainland, as at Red Rock point and at other places, but also passing through the gabbro of the main dikes. One is well known by all who have passed over the portage to the South Fowl lake, where it is conspicuously displayed in the trap-sill on the American side of the boundary. Many such are noted and illustrated by Dr. Norwood, who repeatedly states that they pass not only through the slates, but also through the gabbro of the hills,* a statement, however, which has not been abundantly verified by the Minnesota survey. Many of these, however, may not be post-Manitou.

Mineral veins. Several conspicuous veins, composed almost wholly of calcite and barite, cross the peninsula in a north-south direction. They also contain a little amethystine quartz. Other veins carrying "gray copper" in small amounts cross the peninsula, and appear on the islands south of the mainland. These veins are on sections 32 and 29. Some shallow shafting has been done on the veins that appear on section 29. The minerals thrown out are calcite, barite and amethyst, with the ores pyrite, sphalerite, galenite and chalcopyrite in small amounts. Probably the most valuable product of these veins will be found to be barite.

An enterprise of mining on one of these veins on Governor's island was started some fifteen years ago under the instigation of Maj. T. M. Newsom, and a deep shaft was sunk. With a little copper ore, and less of silver, the work was stopped when the shaft, which was large and well constructed, encountered a body of red granite. This locality has already been described.

Graphite has also attracted attention. It is found in round small masses near the central part of the peninsula about south from Parkerville, embraced in a siliceous rock which has usually been taken for one of the layers of the Wauswaugoning quartzyte, but which is so confusedly invaded by the basic rock that prevails on the peninsula that it is difficult to affirm that it is not in the latter rock as abundantly as in the quartzyte. The basic rock becomes highly silicified by absorption of silica from the older rock along the contact planes.

* Owen's geological survey of Wisconsin, Iowa and Minnesota, pp. 402, 404.

Rock samples, illustrating this area, are as follows: Nos. 228–296 (ninth annual report); Nos. 540–553 and 603–620 (tenth annual report); Nos. 1815–1857 (of notes of 1893); Nos. 2073–2077 (notes of 1896); Nos. 770W–773W (sixteenth annual report); Nos. 559E–571 E.

Supplementary note. Since the foregoing was written a paper by Dr. Elftman has been published in which he describes the glacial lake formed by the obstruction of the lower portion of the Pigeon river by the retreating margin of the lake Superor ice-lobe in the following words:

Lake Omimi. Before the ice had receded beyond mount Josephine it retained a lake of about forty square miles in area, lying in the upper valley of the present Pigeon river. The lake bed has an altitude of 1,255 to 1,360 feet above the sea. Its lowest point is thus about fifty feet higher than the upper stage of lake Duluth. The chief deposit consists of stratified clay, exposed along the Pigeon river and its tributaries. Beaches have as yet not been identified. The western shores of this lake were formed by high rock ridges. The ice-barrier during the largest extent of the lake stood in the vicinity of the western end of the Grand Portage trail. The outlet, which has not been definitely located, was probably toward the southeast, and closely connected with the ice-barrier, which upon receding continually uncovered lower ground. This lake in part occupied a portion of the area previously occupied by the northern ice-lobe. When the ice receded from the vicinity of Grand Portage, lake Omimi disappeared. The name Omimi is taken from the Chippewa name for Pigeon river.—*American Geologist*, vol. xxi, p. 104, 1898.

CHAPTER XXIX.

THE GEOLOGY OF THE VERMILION LAKE PLATE.

(PLATE 86.)

BY N. H. WINCHELL.

Within the area of this plate more fieldwork has been done than within that of any other equal area in northeastern Minnesota. That is not alone because of the economic interest that centres in the Vermilion iron mines, but also because it embraces some of the perplexing and still unsettled problems of the geology of the crystalline rocks.

When the writer first visited the region (1878) it had not been surveyed and divided by the United States government, either into sections or into towns, and he was compelled to rely on a pencil sketch of its coast-line made for him on a foolscap sheet of paper by Bashitanequeb (plate QQ, figure 1), an Indian of Sucker point, who afterwards became one of the most useful guides to the later parties of the survey. This sketch is reproduced on the following page (figure 101).

The first specimens collected (ninth annual report) are referred to their places by reference to this map. In making use of these specimens for this report they have been located as nearly as possible by the sections of the surveyed towns, as will be seen by consulting the petrographic descriptions in vol. v. A later map, colored to show the geological formations, was published in the fifteenth annual report.*

The general topography. The basin of Vermilion lake is broad and shallow. The shore generally rises less than fifty feet within the first ten rods, and throughout the area of this plate the hills rise with rare exceptions less than 100 feet above the surface of the water. Plate QQ, figure 2, from a photograph, gives an idea of the aspect of the lake from a distance. The great tortuosity of its coast line, combined with the frequency of rocky islands and with the slight relief of the surrounding country, all coincide with the general shallowness of the basin. This ridge and its companions, the south ridge and Chester peak,† all consisting of jaspilyte,

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* The published data upon which this final report is in part based are as follows;

N. H. WINCHELL. *Ninth Annual Report*, pp. 96-105; *Thirteenth Report*, pp. 20-31; *Fifteenth Report*, pp. 211-317; *Sixteenth Report*, p. 113; *Eighteenth Report*, pp. 8-12, 27-43. Also unpublished observations in 1893, 1896 and 1898; *Amer. Geol.*, July, 1897, vol. xx, pp. 41-51; *Bulletin vi*, pp. 1-112; *Amer. Geol. vol.* iv, pp. 291-300.

A. WINCHELL. *Fifteenth Annual Report*, pp. 13-28; *Sixteenth Annual Report*, p. 328.

H. V. WINCHELL. *Fifteenth Annual Report*, pp. 413-415; *Sixteenth Report*, pp. 446-450; 458-462.

U. S. GRANT. *Seventeenth Annual Report*, pp. 191-192, 215; field notes of 1893, 1896 and 1898.

A. H. CHESTER. *Eleventh Annual Report*, pp. 160-167.

H. R. SMYTH and J. R. FINLAY. *Trans. Am. Ins. Min. Eng.*, Oct., 1895.

BAYLEY WILLIS. *Tenth Census Report*, vol. xv, pp. 457-467.

† This is commonly corrupted at Tower to *Jasper peak*. The peak was named from Prof. A. H. Chester, who directed the first exploration of the iron ridges at Tower.

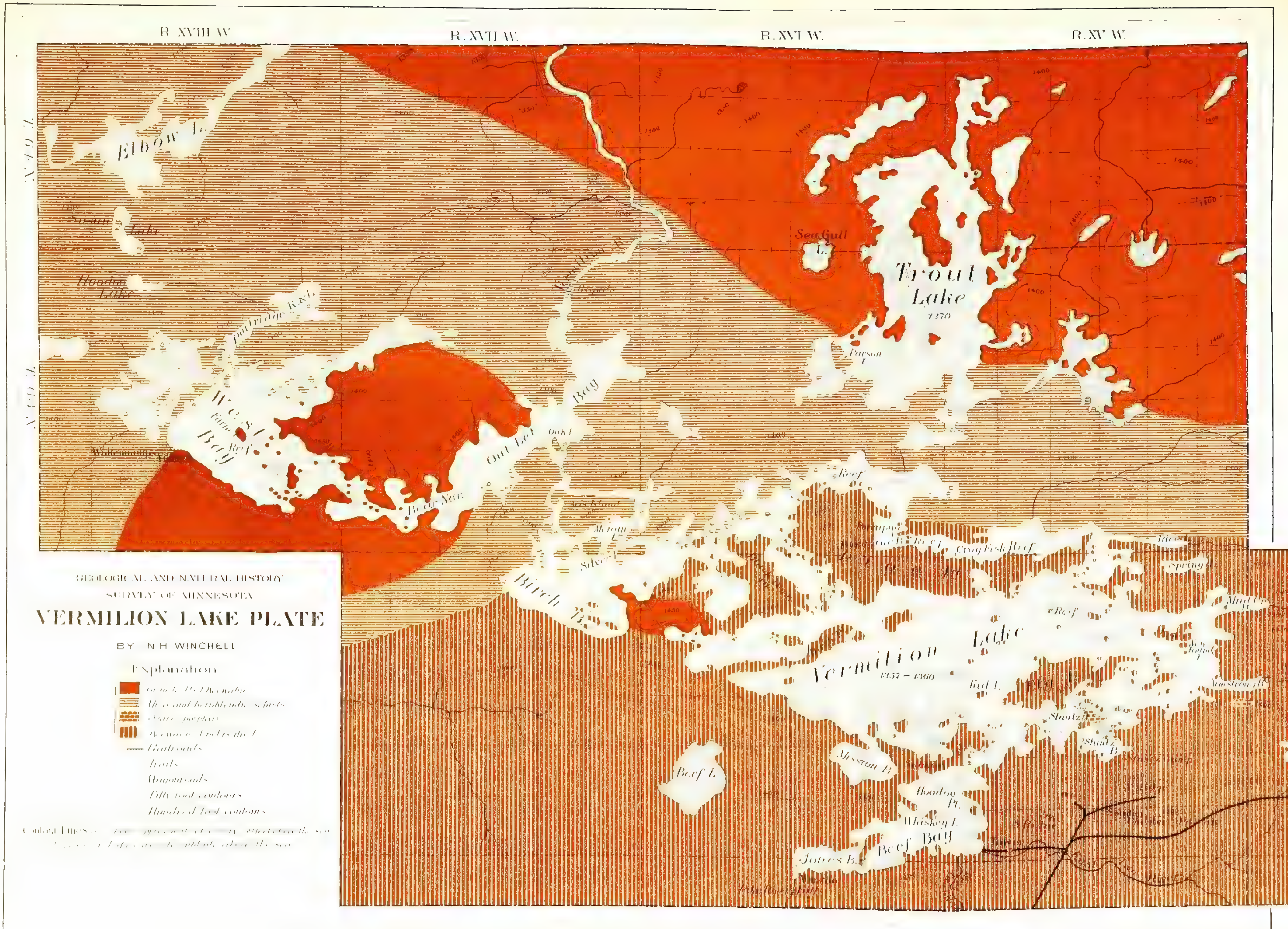
GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA
VERMILION LAKE PLATE
BY N. H. WINCHELL
Explanation
Railroads
R. XVIII W.
R. XVII W.
R. XVI W.
R. XV W.
T. 64 N.
T. 63 N.
Elbow L.
Susan Lake
Hoodoo Lake
West Bay
Bear Nar.
Out Let Bay
Birch B.
Trout Lake
1370
Sea Gull L.
Parson I.
Vermilion Lake
1357 – 1360
Crayfish Reef
Beef Bay
Jones B.
Hoodoo Pt.
Whiskey I.
Mission B.
Reef I.
Stuntz I.
Stuntz B.
Silver I.
Spring I.
Mud Cr. B.
Armstrong B.
Rapids

FIG. 1. BASHITANEQUEB (CHARLEY SUCKER), INDIAN GUIDE, COOK AND CANOEMAN. (p. 522.)

FIG. 2. VIEW OVER VERMILION LAKE, FROM THE NORTH RIDGE. (p. 522.)

FIG. 1. BEACH AT HOODOO POINT, VERMILION LAKE, BACKED BY LACUSTRINE CLAY. (p. 523.)

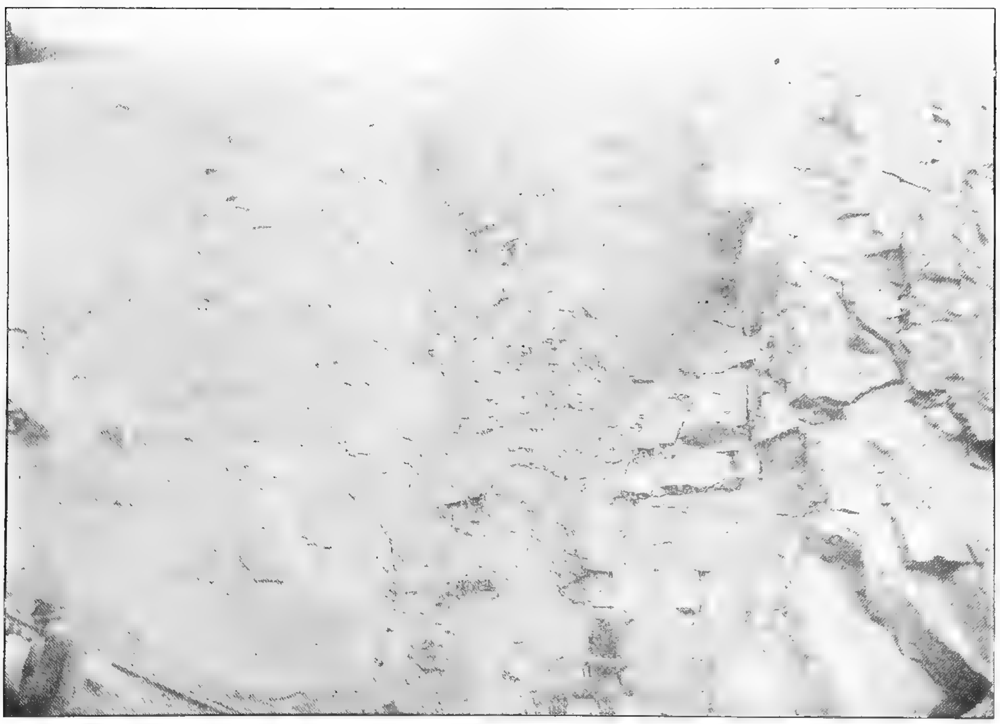

FIG. 2. INTRUSION OF JASPILYTE INTO GREENSTONE, IN THE MANNER OF A DIKE, CAUSED BY FOLDING AND SHEARING PRESSURE. (p. 535.)

essentially, and located in a group, are some of the exceptions alluded to. These rise to 1,550 and 1,600 feet above the ocean, the lake having an elevation of 1,360 feet at high water. It will be seen by consulting the descriptive chapter on the north part of St. Louis county (plate 67), that the Vermilion moraine crosses this area diagonally from northwest to southeast. Indeed, the southern and western coast line is almost wholly formed by this moraine, against which the lake rests as against a uniform barrier, while the lake itself lies elsewhere directly on the rock which is exposed in thousands of places. This moraine is piled on the high ridges at Tower, mainly on the southern slopes (figure 4, plate OO).

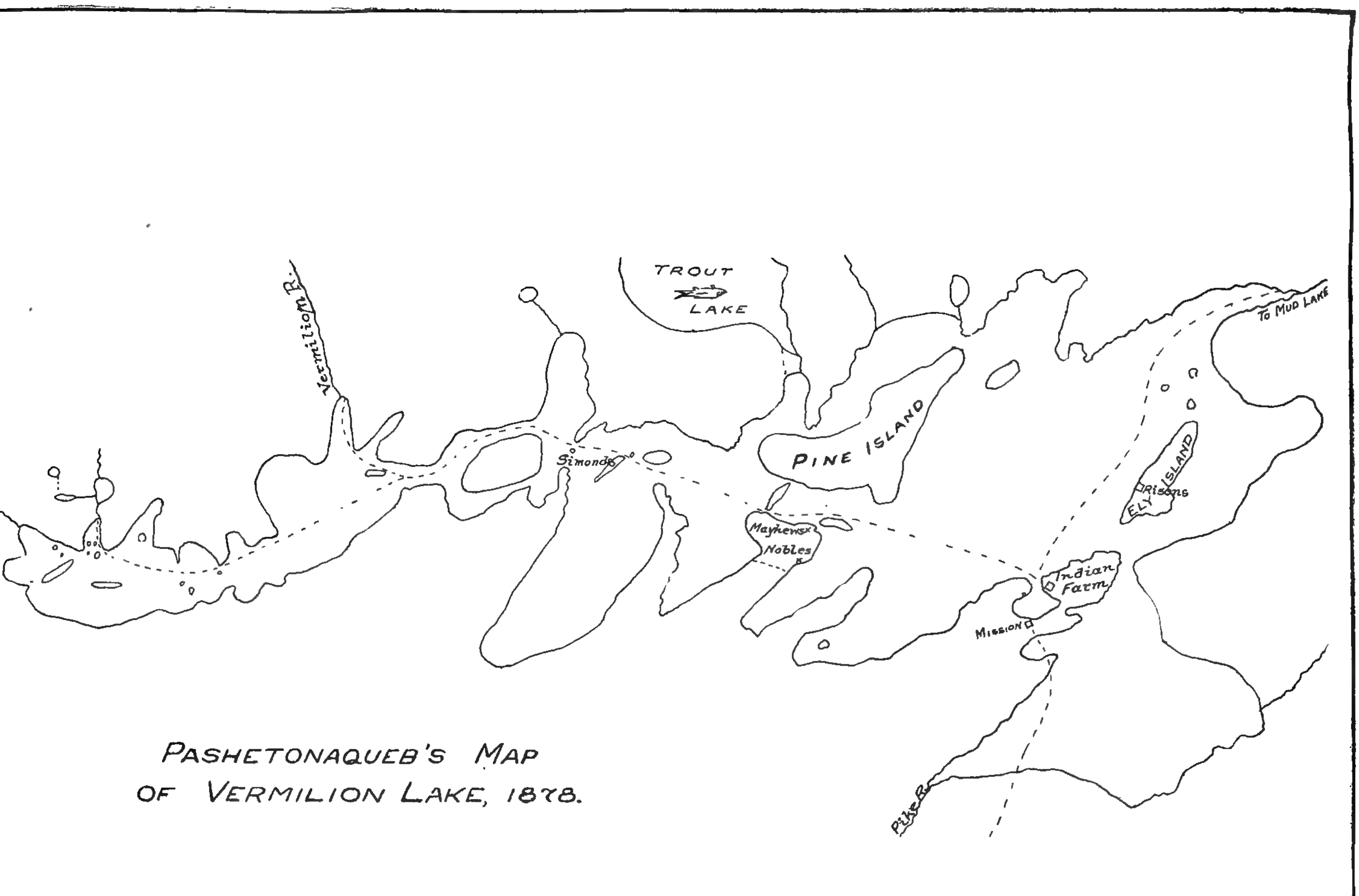

FIG. 101.

The lake shows evidence of having stood, at a former period, about ten or fifteen feet higher. At least, at Hoodoo point and about Mission bay are seen lacustrine clays and sandy beaches (plate RR, figure 1) that rise above the present water level. They may have been formed by a glacial lake, on a partial recession of the ice-margin, and therefore they may not be continuous over the lake basin. There is no gorge-erosion at the point of outlet of the lake (plate S, figures 1 and 2), suffi-

cient to cause that amount of subsidence of the entire lake. The water simply flows over the rock rim of the basin, at its lowest point, and there is apparently no greater erosion than if the operation had continued no longer than a hundred years. The rock is mica schist. This general monotony of surface is characteristic of the oldest formations everywhere in Minnesota.

The Archean. In the Archean are here included the following, enumerated in descending order, the oldest at the bottom of the list:

1. Dikes of diabase.
2. *Upper Keewatin*, including the Stuntz conglomerate and the attendant graywackes, slates and quartzytes; also the siliceous and pebbly green schist of the south ridge (figure 2, plate WW).
3. Granite and igneous gneiss with basic dikes.
4. *Coutchiching*, a crystalline condition of the Lower Keewatin adjoining granitic areas.
5. *Lower Keewatin*, including fragmental greenstones, the jaspilyte ore (figure 1, plate WW), quartz porphyry, sericitic schist, black slaty jaspilyte and massive and agglomeratic greenstone.

The dikes. The youngest rocks of the Vermilion Lake plate area are seen in S. E. ¼ sec. 23, T. 63–18, in the form of two basic dikes (Nos. 2000, 2001, 2002 and 2004; also Nos. 1014G and 1014aG), the last being on Ely island, at the northeast end. These are narrow, non-schistose dikes. They have not been broken nor turned from their courses by any later dynamic action. They are cross-columnar, and finer at the sides than in the centre. They evidently represent the epoch of the latest great disturbance, either Cabotian or Manitou. In thin section they are seen to have the augites well preserved and penetrated in an ophitic manner by the small, sometimes porphyritic, feldspars. There is no indication of pressure nor shearing action.

There are two sets of older diabase dikes that cut the Upper Keewatin. Some are seen cutting the Stuntz conglomerate and one of these sets cuts the other. They are seen as photographed in figure 2, plate SS, but the point of intersection is not here shown. The main series consists of one large dike and several branches and narrow wedge-shaped masses running E. 10° S. (No. 872).

The rock of the other set of dikes is now in the condition of a greenish chloritic schist (see rock No. 873). This series is not so conspicuous, nor so numerous, as the other, but shows two distinct narrow dikes about eight and eighteen inches in width, running 10° N. of E., and thus forming an angle of 20° with the other set.

It was for some time a matter of doubt whether these were true dikes. They manifest a schistose structure parallel with that of the conglomerate, and also parallel with the bedding structure of the region so far as any such is visible. They are soft, easily shattered, and also appear as short, isolated belts, sometimes not running more than ten feet before they pinch out, though one of them can be followed a distance of more than sixty feet, when it becomes invisible by running under turf and bushes. In one case one of these splits and forks round a

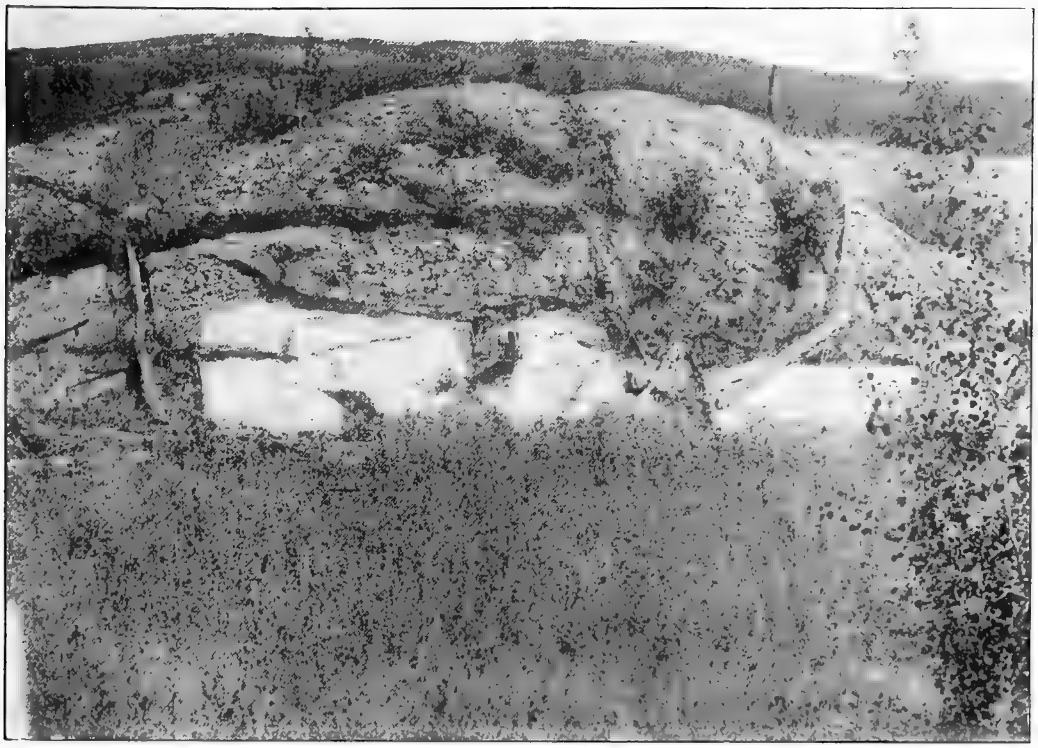

FIG. 1. BLUFF OF STUNTZ CONGLOMERATE, STUNTZ ISLAND, LOOKING SOUTH. (p. 525.)

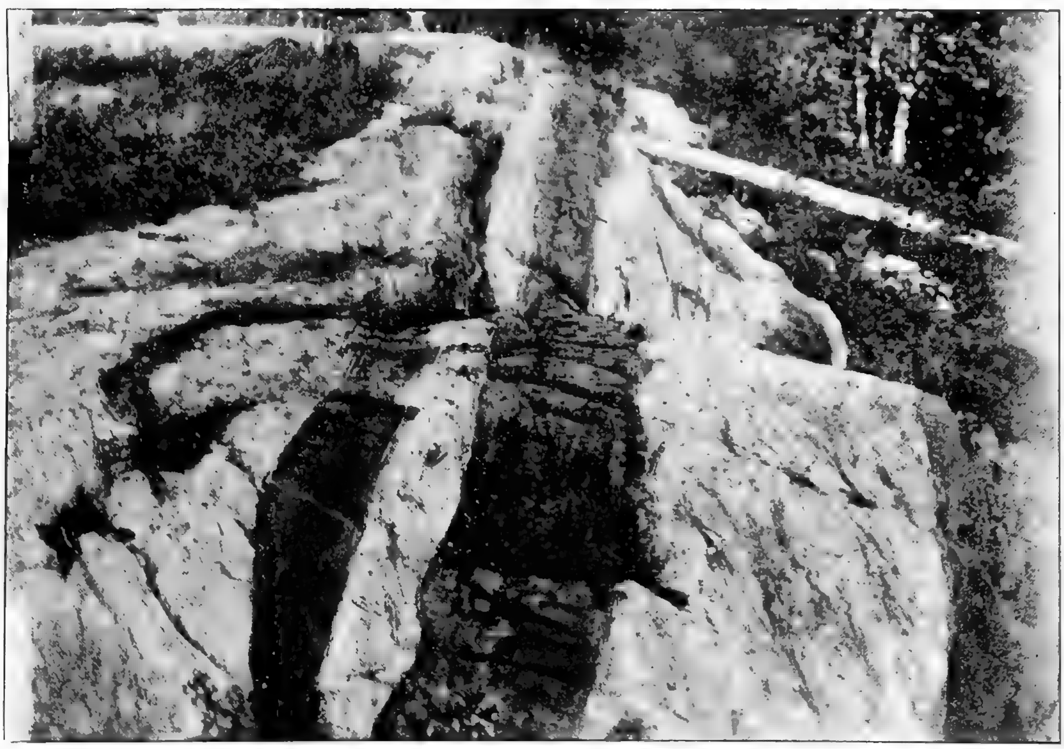

FIG. 2. ARCHEAN DIKES CUTTING THE STUNTZ CONGLOMERATE, STUNTZ ISLAND. (pp. 524, 525.)

FIG. 1. ORIGINAL BANDED JASPILYTE (LOWER KEEWATIN), NORTH RIDGE, TOWER. THE HAMMERS LIE ON BEDS OF SILICEOUS GREEN SCHIST. (pp. 524, 545.)

FIG. 2. CLASTIC, OR SECONDARY JASPILYTE (UPPER KEEWATIN), SHEARED IN GREEN SCHIST. SOUTH RIDGE, TOWER. (pp. 524, 545, 548.)

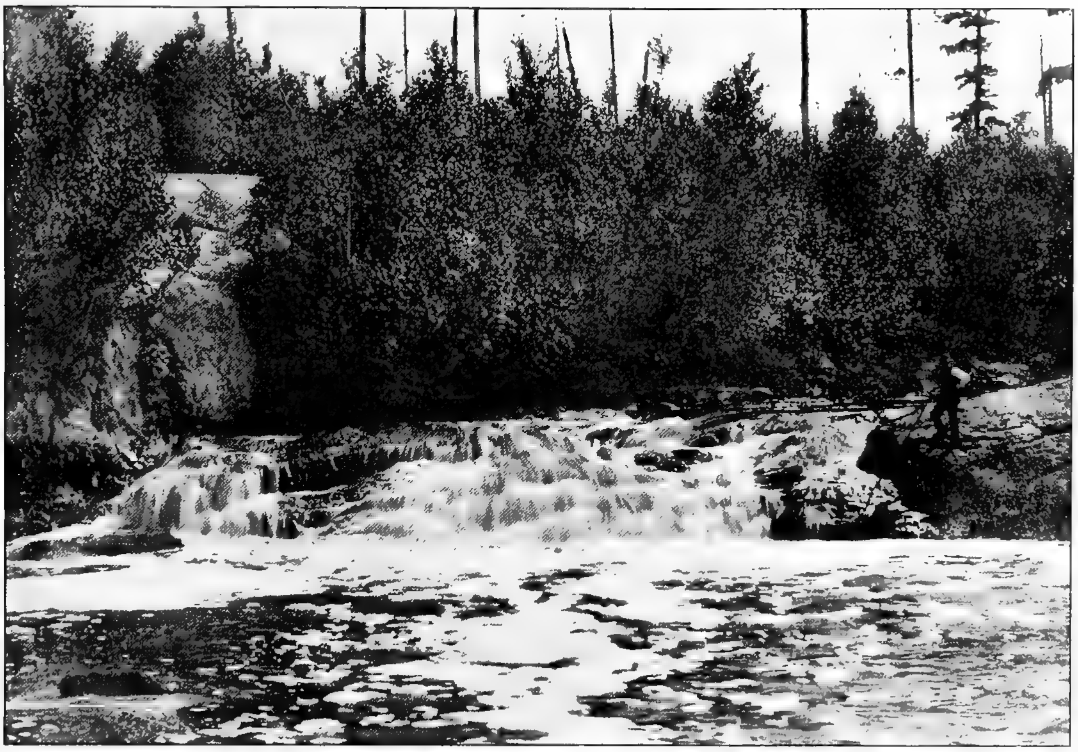

FIG. 1. PIKE RIVER FALLS.

FIG. 2. BOULDER OF STUNTZ CONGLOMERATE SPLIT BY FROST; LYING ON JASPILYTE NORTH OF THE NORTH RIDGE. DIMENSIONS: 15 FEET HIGH AND 18 FEET WIDE. (p. 525.)

portion of the conglomerate. One fork dies out quickly, but the northerly one continues for twenty feet before it is lost under the soil and vegetation. They also contain a few fragments of jasperoid quartz and rarely some round pebbles of more coarsely crystalline rock like themselves, or like the rock of which they, perhaps, originally consisted. That which furnished finally incontestable proof that this system also constitutes a series of true dikes was the discovery, after clearing away the turf, that they cut the other dikes, maintaining their identity of structure and their walls right across them. The dike-like character of the other system is most evident, not only in the manner of crossing the formation and forming angular jogs, but in the basaltic form of the rock and its doleritic nature. The mineral nature of the later system seems now to differ from that of the older only in being more changed by decay. This may be due to the accident of its direction being coincident with the subsequent development of the schistose structure, allowing not only a complete fibrous internal rearrangement, but, afterward, a more ready access to all disintegrating agents. No. 873A is a rounded ball of green rock taken from the second system. Only two or three of these were seen. In both series can be seen pieces of jasperoid rock.

The petrographic characters of the rock of these dikes indicate that the dikes are very old. They are older than the Cabotian of the Keweenawan, for there is another set of fresher diabase dikes that are referable to the Keweenawan. Such occur in the northern part of the lake (rocks Nos. 2001, 2002 and 2004) and probably elsewhere. Similarly two early sets of dikes of basic rock are found on Pine island, north part of sec. 35, T. 63–16. These cut a micaceous graywacke, the strike of which is 10° S. of E. The dikes weather gray, and outwardly greatly resemble the graywacke, but by their structure and their unconformity with the rest of the rock, are seen to be of eruptive origin. Their width varies from three to thirty inches. These dark greenstone dikes cut a light-weathering dike, represented by rock No. 881, at a sharp angle; indeed, the two series are nearly parallel, but by the difference of color the darker dikes can be seen to crowd upon and across the lighter dike. Similar irruptive basic dikes are not uncommon further north, where the granitic dikes also begin to appear. Rock No. 877 represents one seen on the southern shore of Menan island, which appears to have been originally amygdaloidal. These rocks are all very much altered by decay. The feldspars are cloudy with impurities, and the only ferro-magnesian mineral present is a green hornblende. These dikes, therefore, seem to date from Archean time. Still, old as they are, they are perfectly distinct and distinguishable from the rocks that they penetrate.

The Upper Keewatin. This consists of the conglomerate of Stuntz island, and an uncertain amount of graywackes and argillytes. It was not till 1896 that the true relation of this conglomerate to the formation which carries the iron ore at Tower was certainly known; but this conglomerate was thought to be an integral part of that formation. Owing, however, to the publication of a theory of its origin and relations* which not only differed radically from all previous views, but proposed a remarkable hypothesis, some special examination was made of this conglomerate. This was sufficient to settle the main question, although there remain collateral issues that are not settled.

This conglomerate was fully described, and somewhat illustrated, in the fifteenth annual report. Figures 1 and 2 of plate SS, and figure 2 of plate TT of the

*Smyth and Finlay. The geological structure of the western part of the Vermilion range. *Trans. Am. Inst. Min. Eng.*, October, 1895.

present volume represent its outward aspect as photographed in 1886. The last is a view of some boulders of this rock near Tower. The former represents a bluff on Stuntz island.

The geographic extension of this rock it is not possible to define, at present. This is owing to two causes: (1) So long as its taxonomic importance was not appreciated it was not considered necessary to delimit it from the rest of the Keewatin; (2) Owing to the inherent difficulties that attend any attempt to separate it from the rocks on which it lies, or from those into which it graduates upward, it is almost impossible to distinguish it from them. Still, as will be seen by examining the geological map that accompanies the fifteenth annual report, it is there represented *en masse*, as extending eight miles east of Vermilion lake, and to recur again at Ogishke Muncie lake. The name Ogishke conglomerate was extended over the whole. On the map accompanying the bulletin devoted to the iron ores (No. 6) this rock was not separately represented by a color, at any place, but it was included in the Keewatin. At the same time the character that denoted a conglomeratic structure was expressed on this map in numerous places, both in the Keewatin, in the Coutchiching

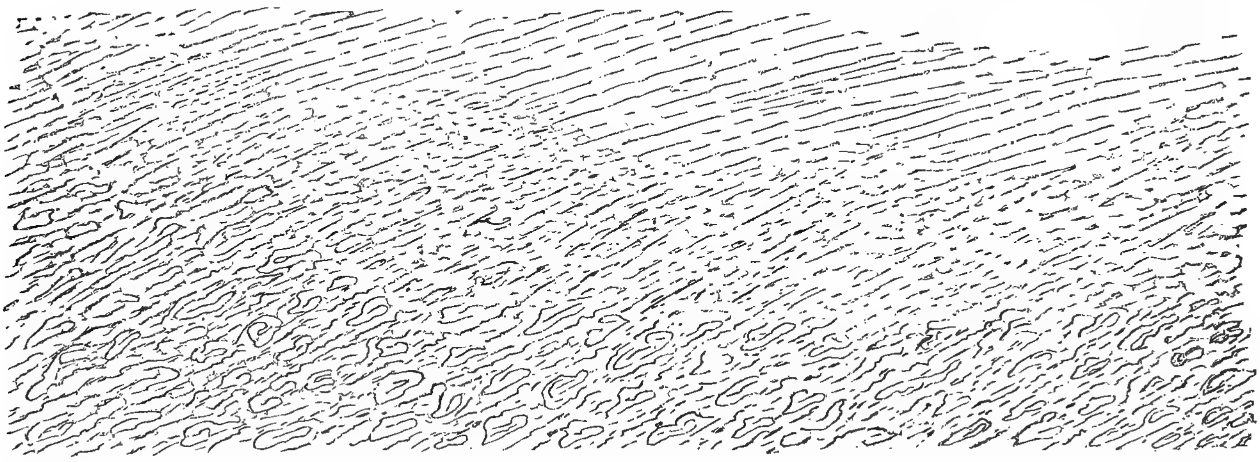

FIG. 102. SHOWING DIFFERENTLY SCHISTOSE BELTS IN THE FELSITIC CONGLOMERATE OF STUNTZ ISLAND AND THE GRADUAL TRANSITION TO THE UNDERLYING PARENT ROCK.

and in the region of Saganaga lake. The figure above illustrates a fact which has been found to be a common, and, so far as known, an invariable, feature of this conglomerate at the point of overlie upon the older formations. This is from the fifteenth annual report, page 313. The transition from the coarsely pebbly conglomerate is gradual, downward, through finer and finer sediments, which lie on the older rock nearly *in situ* of their point of disintegration. They therefore greatly resemble, on consolidation, the rock from which they are derived. The sameness is increased by the evident downward decay which the older rock suffered at the point of overlie of the later; and the differences are further obscured by the subsequent pressing and shearing which both have undergone. Similar fine sediments recur at higher intervals in the strata.

In the central part of Stuntz island, where the above figure was sketched, the structure of the rock varies in belts, along indistinct lines of contact. The rock is essentially alike in composition, but different in the fineness of the sub-crystalline grains and in the schistic structure. The finer grain and structure are apparently cut across by lines of contact with other rock, but a parallel schistose structure, though coarser, is perpetuated in the coarser rock. These are both without apparent boulders, are fine-grained, feldspathic, without apparent free quartz, and are represented by No. 2H, the coarser one embracing small lenticular bits of soft, greenish serpentinous slate. They both have an imperfect basaltic jointage. Beyond these, that is, toward the south, a coarser rock again comes in, having a similar line of contact and transition, the fine-grained belt being about twelve feet across. This has the same general color and finely sub-crystalline feldspathic composition, but is not so completely homogeneous. On careful examination and particularly on weathered, or burnt, surfaces, can be seen, distinctly, small areas of lighter color and denser grain, though more porphyritic, with some elongation in the direction of the schistosity. The forms of these areas are seen to be rounded whenever their shapes are made evident by the exfoliation of the surface by the action of the fires that have rendered the island nearly bare rock, simulating those of the conglomerate, and suggesting that even within this homogeneous rock are still the nuclei of pebbles and stones, and that the whole of it may have been at first a coarse conglomerate of pebbles of one sort of rock.

The conglomerate itself is coarse, some of the stones being more than a foot across. Stones make up the whole of it, in some places, but in others they are small and scattered, or fail entirely. There is, even in the coarsest portion, a little schistose, sericitic (?) material, with all its scales and fibres elongated in the direction of the greater diameter of the pebbles, that twists about between the boulders, its laminæ about parallel to the sides of the inclosed stones. The stones and the matrix have a general similarity or approximate identity of mineral composition and color. The weathering color, particularly of the stones, is nearly white, but there is a dull, greenish tinge in the matrix. On fracture, a light green color is at once apparent in the stones, and a darker green or a grayish green in the matrix. The stones contain much semi-rounded quartz, in grains of all sizes up to one-sixteenth inch across, while the matrix not only contains these, but seems to be porphyritic sometimes with white feldspar. The pebbles themselves are chiefly a greenish quartz-porphyry and show a fibrous internal elongation in the same direction as that of the matrix, but they are more durable than a matrix, and often stand out distinctly on the weathered surfaces.

This conglomerate also contains many pieces of jasperoid quartz showing a fine banding like that in the ore rock of the mines. Sometimes this is placed across the schistose structure, but it generally is parallel with it, and the pieces then seem to have the same superinduced lengthening in that direction which is evinced by the rounded boulders of the other kinds of rock. This seems to show unmistakably a difference of age between the jaspilyte of the hills and the chloritic schists associated with it and this conglomerate, and this is shown more fully by facts to be stated later.

The lengthening or compressing of the stones in this conglomerate need not be attributed to the effect of the superinduced schistosity, which must have been caused since the later system of dikes above referred to, inasmuch as those dikes are schistose in the same manner and direction; for if any stone, whatever its source or nature, not absolutely round, be cast into a liquid, whether water or sediment, it would assume

a position when it came to rest at the bottom, approximately with its flattened sides, or, at least, its elongation, parallel with the bottom on which it came to rest, and would remain parallel with the successive stratification, in whatever direction the bedding might be tilted. There is no evident sedimentary structure in this conglomerate, but there is a coarse structure, somewhat wavy, simulating a succession of sedimentary or other manner of accumulation which dips toward the south, or stands nearly vertical.

In the northern part of Stuntz island the rock of which lies below the conglomerate (figure 1, plate SS) are veins of quartz, and others occur on the north side of Ely island and on the east shore of Stuntz island, some of which have been thought to contain traces of gold, and have been wrought to some extent (in 1866). Some of these veins are four feet or more in width, but they are irregular and pinch out at both ends, and sometimes they run into narrow veins or deposits of quartz, occupying irregular openings that are about parallel with the main structure of the rock, *i. e.*, extending east and west.

Frequently are seen, especially in the finer parts on the north side of Stuntz island, light-green serpentinous pebbles or fragments (Nos. 874B and 2aH). They are generally elongated with the schistose structure, and their schistose structure runs in the same direction. The source of these fragments is entirely unknown, as no such rock is known in the region, but they were undoubtedly accumulated with the debris of the conglomerate, or are inclusions in the massive quartz-porphyry.

On close inspection of the rock that forms the northern half of Stuntz island, although it is apparently entirely homogeneous, yet in nearly all parts there is an indistinct internal structure, evinced by faint blotches of lighter color, and by warping of the laminæ about such invisible shapes within the rock mass, that shows there are inequalities in the material, and in the structure, or fragments of about the same material as the matrix. These indefinite characters blend with the surrounding mass, and are so nearly identical in composition and grain that they can be identified only where the process of weathering brings their forms partially into view.* In the northern part of the island, however, are seen none of the jasper fragments that are so common in the southern. The rock instead contains in some places much free quartz, some of it being in coarse phenocrysts or clastic grains as large as a quarter of an inch in diameter. Compare figure 102.

Origin of the Stuntz conglomerate. Since the boulders of quartz-porphyry which compose the bulk of the material in the coarse portions of this conglomerate, and the jasper pieces, though placed with their elongated axes parallel with the schistose structure, and also parallel with a rude foliation which might be called bedding,

* This structure, if not due to a fragmental origin, here, can only be accounted for, as it appears, by a multiple fracture and shearing, similar to that assumed by Messrs. Smyth and Finlay to account for the conglomerate itself.

neither of them partake of the schistose structure, and apparently are not changed from their original shapes, it is evident that the general elongation of the boulders is not due to the schistizing process, but that they assumed the positions that they have, as well as their forms, prior to, at least independently of, that process, and under the action of some force more powerful and more widespread than it. It could be no other than that which originated the conglomerate itself. It follows also that the material surrounding these pebbles, having acquired the schistose structure, must have been in some way different from the pebbles, or must have been treated in a different manner. It is hardly possible to suppose that it has been differently treated in the dynamical strains to which the rock has been submitted. It remains, therefore, to account for an original difference between the stones and the matrix. To the writer there seem to be but two possible ways to explain such a difference, viz.:

1. A fragmental accumulation as a conglomerate, the fine parts of the sediment surrounding the pebbles.

2. A brecciation such as that supposed by Messrs. Smyth and Finlay.

It is no novel thing to find a conglomerate sheared and rendered schistose. Even common gravitative pressure will develop a slatiness in a fine-grained rock. Greater pressure will produce a similar structure in a coarser-grained rock, and multiple pressure in different directions will render such rocks schistose. This schistosity, however, is attributable to the movement of the individual fine grains on themselves and the development of muscovite, not to crushing. If in such a rock coarser parts are included, in the form of grains of the same composition as the finer grains, they also simply move amongst the finer grains, and are less crushed than the finer ones. It results therefore that, in the pressure of a conglomerate, slatiness will first appear in the finer portions, and that a schistosity, resulting from pressures short of crushing, will appear only in the matrix. Hence the appearance of the Stuntz Island conglomerate is only an ordinary phenomenon, so far as these features extend, and its structure would be immediately referred by any observer to the ordinary shearing and pressure of an ordinary siliceous conglomerate.

If such be the nature of this conglomerate it would be almost inevitable that the pebbles should be of different kinds.

On the other hand, as already stated, it has been proposed to refer this rock to a very different origin. Messrs. Smyth and Finlay* have urged with great plausibility and acumen that the fragmental character is due to the brecciation *in situ* of an original massive quartz-porphyry. They suppose that by a shearing along certain definite planes parallel to each other, and along another set parallel to each other, but making a large angle, approaching 90°, with the other set, and also along a third

* *Op. cit.*

set of planes approximately perpendicular to both these, the whole rock was cut into cuboidal blocks. This shearing may have all been cotemporary, and during one general epoch of opposing movements, or the shear-planes in different directions may have developed at long separated intervals. Cotemporary with the cutting of the rock into blocks, there was much friction of the blocks on themselves. This friction rounded the blocks and smoothed their exteriors. The particles removed remained *in situ* to produce, on final consolidation, the matrix which now surrounds the stones, and on further pressure this has acquired its schistosity. Under this hypothesis the stones and the matrix are of the same material.

To the writer, however, this explanation appears far-fetched, and, on due examination, wholly inadequate and contrary to a number of facts which will be mentioned.

The nature of the stones is various. Not to mention again the occurrence of red jasperoid fragments, and of serpentinous slate pieces, the stones which may be called in general quartz-porphyry differ. Some are coarse and some fine. Some are charged with small feldspars and others are not. Some bear porphyritic quartzes and some do not. Some are quite light-colored and some are dark-colored, and amongst them is a liberal sprinkling of fine quartzyte or white jaspilyte, in which no feldspathic ingredient is visible. In the latter sometimes the characteristic banding, which marks the red and black jaspilyte, is faintly developed, showing its alliance with the Tower hills. It is, of course, true that even on the hypothesis of extreme brecciation, such as urged by Messrs. Smyth and Finlay, there might be variations of lithology in the original rock, for a quartz-porphyry is only a phase in a process of crystallization of an acid rock, and at some other places it might contain feldspars, and in others it might lack even the quartzes. But these variations would be such as would take place over large intervals. The breccia that would result from such a rock at any place would be practically a homogenous breccia. There would be no mingling of rock of different sorts in the same square foot, or even in the same square rod—at least it would not be the rule to find such rocks mingled in the breccia.

But in this "breccia" such rocks are mingled everywhere. No one can inspect the weathered knobs without finding such contrasts, although, at the same time, there is a general and broad similarity. Sometimes these contrasting rocks are *absolutely in contact.* A pebble may be found different in texture from all those that surround it, yet in contact, or nearly in contact, with them. It is hardly reasonable to suppose, even assuming such original differences in the rock, that the multiple breccia and shear-planes appealed to by Messrs. Smyth and Finlay would, in nature, so guide their courses as to exactly cut out an isolated variation in the rock and allow it to maintain its differences on all sides without sharing them with its neighbors. Still

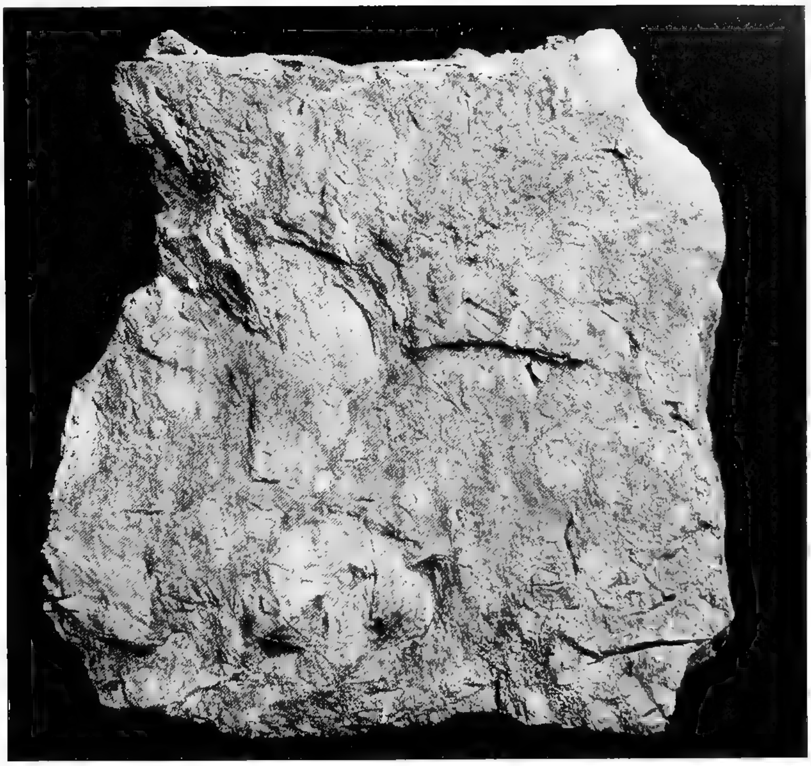

FIG. 1. SLAB OF THE STUNTZ CONGLOMERATE. (p. 531.)

FIG. 2. BOULDER OF GRANITE LYING ON THE AGGLOMERATE AT ELY.

more is necessary, if the theory of multiple shear-planes be true, for those shear-planes must have treated a great variety of lithological differences with the same partiality. In short, instead of being a homogeneous quartz-porphyry cut by three series of breccia planes, it was a very changeable quartz-porphyry cut by such planes as would isolate the various phases into separate blocks without once dividing them in such a manner that any one block shall show two or more phases.

Plate UU, figure 1, is reduced to one-third natural size from a photograph of a slab about twelve inches in greater diameter, found on the beach. Accidentally it shows the following parts, as numbered in the figure below. Equally varied surfaces are seen in great profusion in some parts of the conglomerate, but in others but little variety appears.

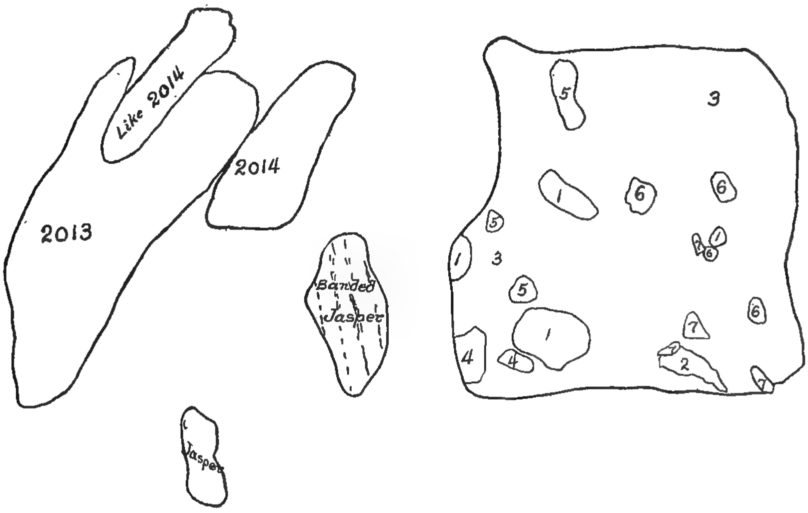

FIG. 103. PEBBLES IN THE STUNTZ CONGLOMERATE.

1—Light-weathering quartz porphyry.
2—Coarse, granular, very feldspathic patch, of rather irregular outline, probably a part of the matrix.
3—Coarse grit, having no definite outlines but really constituting the major part of the whole slab. In this are distinct quartz grains and feldspar crystals.
4—Indistinctly banded quartzyte in rounded pebbles.
5—White quartzyte in rounded pebbles.
6—Gray quartzyte in rounded pebbles.
7—Nearly black and flinty angular fragments.

Only the larger pieces are numbered. Smaller ones of the same kinds of rock are scattered and mingled together throughout the slab. In this slab there is not a great variation in the quartz-porphyry proper, perhaps no greater than might exist in a practically homogeneous rock, and it might still be claimed that the jasperoid pebbles were acquired, as supposed by Messrs. Smyth and Findlay, by the rupturing of the jasper and quartzytes of the iron-bearing rocks at the time of the intrusion of the quartz-porphyry. But pebbles that were collected by the writer, absolutely in contact, show great differences, as quartz-porphyry, some being almost entirely crystalline and others free from all visible crystals. Such are rocks Nos. 2010 and 2011. Of these the latter is a coarsely granular rock, apparently the matrix of the other, which is a very fine-grained pebble. In this case, on the hypothesis of brecciation

and shearing along planes, the "flour of attrition" is much coarser in constituent grain than the rock from which it was derived.

No. 2013 (figure 103) is coarse-grained, and No. 2014 is fine-grained, but they came from contacting pebbles, one about fifteen inches in longer diameter, and the other about ten inches, lying as represented above. While these two stones consist essentially of the same minerals, as seen in thin section, viz., of quartz, a striated feldspar and a non-striated feldspar, muscovite and calcite, the manner of distribution of these minerals is very different in the two. In No. 2013, the phenocrysts make up the most of the rock, and they are frequently in contact, while the surrounding fine-grained matter has a schistosity which is rather rigid and rarely accommodates itself to these crystals, evinced mostly by the bright polarizing colors of the muscovite as they lie between the crystals. The feldspars are much decayed, giving rise to calcite and to muscovite. Some of the quartzes are large, but, along with the feldspars, they have been broken by mechanical pressure, and their fragments are sometimes strewn in the finer matrix. Rock No. 2014 has but very rare crystals of the first consolidation. Indeed, in the whole slide are but two fragments of such quartz crystals and two feldspar crystals, the rock consisting essentially of a close, fibrous, fine-grained, complex of quartz, muscovite and feldspar, all evidently of secondary origin, and developed in consequence of and perhaps cotemporary with the shearing. That this fine material cannot be the result of crushing and of shearing of a rock largely crystalline, and like rock No. 2013, is plain from the fact that four crystals remain not crushed. It is evident that the stone No. 2014 came from a different rock from that which supplied No. 2013, *i. e.*, from a portion of the general quartz-porphyry which must have been some distance separate from that portion that supplied No. 2013. It is evident that they could not have been contiguous parts of the same mass.

Such contrasting and contacting stones of equal size and smaller are common in some places, but over considerable areas they are not so evident. Rocks Nos. 2017 and 2018, both from pebbles, thus differ. They are from the same general locality as Nos. 2013 and 2014, viz., the peninsula forming the S. E. ¼ sec. 20, T. 62–15. (The characters of these rock samples are given in vol. v.)

Non-conformity on the iron formation. Finally, on the same section (sec. 20, T. 62–15), the non-conformable overlie of the conglomerate on the jaspilyte is exposed, the conglomerate graduating downward into a debris of jaspilyte in angular pieces, and upward into quartzyte, graywacke and slate, the whole having a sedimentary structure and succession, and a dip of about 55° toward the south, away from the jaspilyte. All over this peninsula, which occupies the most of the southeast quarter of the section, are exposures of the two formations, and of the contact plane between them. The jasper and siliceous slates stand nearly vertical, and the con-

glomerate shows great variations. Where it is over the jasper it contains a large percentage of jasper fragments, and where it is over the greenstones it consists largely of debris from the greenstone. The material most abundantly supplied is a debris from quartz-porphyry, and that debris forms beds which are dense and firm, and might be mistaken for genuine quartz-porphyry, in the same manner as the debris from a granite, when recomposed, might be mistaken for a true granite. In this case, however, such dense gray rock graduates in one direction into coarser and coarser debris and really becomes conglomeratic, and in the other into quartzyte and into siliceous schists and slates, and apparently into some of the argillytes. Such a succession is illustrated by the figure subjoined. This was sketched from the natural exposure and the strata are illustrated by the samples as numbered. The dip is to the south about 45° to 55°, and the exposure is at the shore on the west side of the little bay which enters the peninsula from the northeast, and probably within the belt represented by Smyth and Finlay as the "third belt of quartz-porphyry," the extremity of the point being the first.

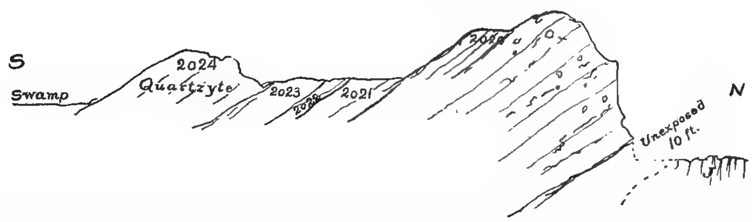

FIG. 104. NON-CONFORMITY OF THE UPPER KEEWATIN ON THE JASPILYTE OF THE LOWER KEEWATIN.

The small area of jaspilyte is exposed about ten feet from the base of the nearly vertical cliff of conglomerate. The conglomerate layer here has an estimated thickness of seventy-five feet. It is in no way different from numerous other exposures, except that toward the base it is largely composed of jaspilyte fragments evidently derived from the underlying rock. The unexposed interval is about ten feet. In the base of the cliff the jasper fragments compose, as estimated, nine-tenths of the whole, becoming fewer higher up. On the southern slope of this conglomerate is rock No. 2020, which is a finer condition of similar debris, densely compact, of a gray color within, weathering white, with scattering, very fine quartz fragments. It is a narrow sheet adherent on the dipping face of the conglomerate. It falls away, after about ten feet, and graduates into rock No. 2021, which also is ten feet thick. This is more siliceous and rather coarser, the clear, glassy quartzes being quite abundant. This contains a few slivers or elongated fragments of some dark mineral or rock (slate?). Next south is rock No. 2022, which has a darker weather-color, and within is quite dark, with a greenish tint. It apparently is more feldspathic than siliceous; it is fine grained, but abounds in a coarsely foliated and cleavable mineral, which, for the most part, runs with the structure. Its feel is not so siliceous and sharp as No. 2021,

but more smooth. It is only about two feet thick, but it contains some pieces, or pebbles, from a quartz-porphyry, or a rock resembling it, which weather white. It varies to rock No. 2023, making in all a thickness of twelve feet. This last rock is still dark, has scattered cubes of pyrite nearly a quarter of an inch on a side, is strongly schistose, and rather fine grained, approaching a coarse argillyte. Lying on these beds is rock No. 2024, a gray quartzyte, harsh and sharp, with fine shreds of what appears to be black slate. This is almost identical with rock No. 2021. This passes under the swamp.

For the petrographic characters of these rocks (Nos. 2016–2024), in detail, the reader is referred to another chapter. In general, however, for a summarized description, they are all affected by a structure which makes them split more easily in a direction about east and west than in any other, this being the schistose direction of all the rocks of the region. This schistosity is most developed in rocks Nos. 2022 and 2023, and in the others it gives an imperfect rift or "grain." They are all siliceous, but they differ amongst themselves. Those sections that are made from pebbles of the conglomerate are homogeneous, but those made from the finer parts of the stratigraphic series show a composite composition characteristic of fragmental rocks. There is evident, even in the quartz-porphyry pebbles, more or less fracturing of the individual quartzes, and somewhat of alteration of the rock mass, but the forms of the grains and the homogeneousness of the matrix surrounding them are in marked contrast with the structures of the detrital material.

As nearly as can be determined this outcrop, including all its parts, falls into one of the belts of "quartz-porphyry" which are supposed, by Messrs. Smyth and Finlay, to extend across the peninsula as intrusions in the jasper. On the contrary this is but an isolated patch of the fragmental base of the overlying formation. All the other exposures of this rock on the peninsula, but not including any intrusive dikes of quartz-porphyry, are of the same nature, structurally, so far as known, and instead of being intrusive are all bedded in the same way, and, in some cases, the underlying formation is visible.

The conglomerate varies laterally. Near the centre of this peninsula are interesting features, described by the writer in 1886.*

On sec. 20, T. 62–15, the graywacke becomes coarser, with arenaceous grains, and gradually assumes the character of a fine jaspery conglomerate in which the pebbles are arenaceous quartzyte of a somewhat amethystine hue. These conglomerate beds are from an inch to twelve inches in thickness, and alternate regularly with argillyte, following the latter in all its tortuosities. It is twisted back and forth, broken, folded and "shortened."

In some places it becomes very coarse, and by the longitudinal shortening it is made to swell out in lenticular or in very irregular bunches, the fine pebbles being mingled with the coarser ones. The pebbles are from the size of a mustard seed to peas, and also larger, and the matrix is a green soft schist which, also, is undistinguishable from argillyte in some of its stages of change. In those places where the aggregation seems to have taken place laterally, the pieces are coarser and the cementing rock is not so commonly and so plainly the soft green schist mentioned, but is siliceous. Most of the pebbles are jasperoid rock, but occasionally there is one of different rock. These latter are found in the coarser portions.

* *Fifteenth Annual Report*, pp. 239–243 and 315.

In other places, in the graywacke, are seen some pebbles, two or three inches in their longer diameter, of the same kind of rock as the pebbles in the conglomerate of Stuntz island, mingled with these fine jasper conglomerate bands. Sometimes these pebbles, much finer, make really the most of the fine conglomerate. Such conglomerate bands, however, are narrow and not common here.

In still other places there is a confused breccia, or apparently a mingling, at least, of graywacke, argillyte, sericitic schist, conglomerate and felsyte. Graywacke and argillyte constitute the greater part of the rock at the surface, particularly in the northern portions of the peninsula. The bedding direction of this, while distorted and reversed over small spaces, yet runs in general nearly coincident with the schistose structure, and is nearly vertical. Toward the south further the peninsula develops into a prominent ridge, elongated northwest and southeast, consisting of a coarse breccia of jaspilyte. This extends several rods, gradually acquiring more rounded pebbles of jasper, then rounded pebbles like those seen in the Stuntz island conglomerate (the jasper pebbles becoming white quartzyte), and at last, just before it disappears on the east side of the point, it presents very much the aspect of the conglomerate which forms the bold shore line on the north side of the point in section 21, and which extends to Stuntz island. About half the pebbles are of white quartzyte, the rest being white quartz-porphyry. It has some bands of fine greenish schist running conformably through it, the same also forming the matrix.

Further north, on the same point, near the centre of the quarter section, is another exposure of jaspilyte, some of it being hematitic. It is twisted, broken, and in general has a banded strike toward the north, then to the northwest, and then about west, and suddenly ceases. The rock graduates, toward the north further, into the same green schist, which at once becomes a conglomerate of white quartzyte and quartz-porphyry. This jasper area, which rises so as to form some of the higher parts of the peninsula, is itself a conglomerate, as it holds some rounded as well as angular pieces. Indeed, there are strata or belts of fine jasper conglomerate, with the schist matrix, running zigzag through the coarse mass, not conformable with the banding of the main jasper masses, but at various angles. In the midst of the whole can sometimes be seen small patches of the green schist that forms the matrix.

Pseudo igneous rocks. The green schist here mentioned appears like that seen on the ridge north of Tower (south ridge), and it is sometimes charged with fine fragments of the white quartzyte derived from the ore beds. It not only runs about amongst the sub-angular large masses, but where it is free from them it sometimes becomes very much like some of the siliceous slates, and even graduates into graywacke (No. 1H). These both present many of the outward features of igneous rocks, but, as will be shown, these features are illusory, and only such as are seen in the jaspilyte and in the argillyte of the region, due to folding and crushing of the strata upon each other. The rock No. 1H, for instance, which is a coarsely granular rock, or graywacke, made up very largely of debris from a quartz-porphyry, is, on section 20, associated unconformably with finer graywacke and argillyte. It is not here generally spread, but a patch about thirty feet across strikes diagonally across the graywacke. It has a pseudo-basaltic, columnar structure and contains semi-rounded quartz grains distributed somewhat like quartz in a quartz-porphyry, though not of uniform size. This belt extends toward the east but seems to divide into two parts.

Similar intrusive action on the part of the jaspilyte into the adjoining greenstone has been taken to show the igneous origin of the jaspilyte. A so-called "dike" of jaspilyte was formerly distinctly exposed in one of the excavations for mining in the north ridge (figure 2, plate RR). There are numerous instances about Vermilion lake in the region between the mines and the lake, in which the graywacke beds for the same reason are caused to penetrate intrusively into the argillytes. Some were once described and illustrated (fifteenth report, pp. 237–244) in order to show that

on this evidence for the igneous origin of the jaspilyte nearly all the rocks of the region would have to be classed as igneous. On the "burnt forties" similar abrupt and incongruous contacts are seen to occur between the Stuntz conglomerate and the jaspilyte. Here the folds were broader, and the contacts bring out the semblance of "dikes" of some size and length, and other apparently igneous intrusion.

At a place northeast from where this rock divides, following an exposed low ridge of rock mostly of slaty graywacke and of graywacke, the latter rock is seen to change across the bedding to fissile argillyte, then to a sericitic schist, then to hold masses of jaspery quartzyte and black chert, the schistose structure winding about them as near Tower, and filling all their sinuosities. This observation shows the intimate relation between this green schist and the argillyte, one changing to the other. In this green schist are not only large masses of jaspilyte, but pebbles of granular white quartzyte like that of the ore rock, some of the latter being an inch or two in diameter.

Conclusion. It may be said, therefore, that this conglomerate performs completely the function of a basal fragmental stratum, varying in composition in accordance with the variation of the older formation. The most remarkable variation is to the green schist which embraces the jaspilyte fragments. If it be remembered that the schistosity is wholly a secondary feature, and that a great greenstone terrane is the main rock of the iron formation, it is easy to understand that greenstone debris would in some places be a noticeable feature even in the basal and coarse parts of the conglomerate. This would, however, be rare, inasmuch as such debris could hardly be expected to be lodged generally in those places where the coarse jasper pieces only could find rest, but it would be carried to stiller waters, and then would be dropped with the gentler sedimentation, mingling with the graywackes and the argillytes in the most perfect sedimentary structure. At the bottom of the conglomerate it would necessarily be only in sheltered places, as between large jasper pieces, which are sometimes 50 to 100 feet in diameter, that this debris could remain; or it could be deposited on subsidence of a coast line hitherto greatly eroded, directly upon the coarse conglomerate which before could not retain it. Such features are visible on the "south ridge" near Tower, and are even more perfectly exemplified than on sec. 20, T. 62-15. The gradations of the schist there may be seen in different conditions.* This subject is further treated in the chapter devoted to *Structural Geology*.†

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*Compare same descriptions and plates in *Bulletin No. vi.*, pp. 49-50, 52-56, plate iii.

†Several of the minor conclusions of Messrs. Smyth and Finlay are based on faulty observations, and it is hardly necessary to refute them, since their major conclusion is shown to be erroneous. Indeed, the whole complex and entirely imaginary structural scheme which they apply to the Vermilion range, at Tower, falls to the ground.

There may be mentioned, however, as faults of their paper:

1. The parting planes which they illustrate in plate (figure 4), as the original shear planes along which the formation was cut, as supposed, into cuboidal blocks, appear to not be shear planes (at the left of the figure), but later jointage, and have no

The source of the pebbles of the Stuntz conglomerate. Recent re-examination in the vicinity of Tower has also shown the existence of the parent rock in the various phases seen in the pebbles. It is in the form of short ridges that extend east and west, and is microscopically so similar to some of the graywackes, which consist of debris derived from it, that it has not been differentiated from the graywackes. It is not known how extensively this rock underlies Vermilion lake, but it is probably the source of some of the felsitic sericitic schists seen about the northeastern environs along the east shores and about Birch bay to the northwest. It probably forms the northern and eastern portions of Stuntz island, the whole of a high island lying just east of the eastern entrance to Stuntz bay, and constitutes the most northerly of the parallel ridges on the so-called "burnt forties." The section corner of secs. 13, 14, 23 and 24, T. 62–15, is on a ridge of this kind, but the rest of the ridges lying next south are composed of fragmental rock, mainly of conglomerate and graywacke. In this conspicuous ridge, which rises perhaps 200 feet above Vermilion lake, the rock is a gray quartz-porphyry with some feldspars. It is not pebbly. It contains scattered, angular or subrounded pieces of greenstone, but none of quartz-porphyry or of jaspilyte. It is massive, except for a rather weak schistosity superinduced by pressure (No. 2270). In some places it weathers pinkish, probably from abundance of orthoclastic material, approximating a granitic structure (No. 2271).

It is likely that other places could be found composed of this rock, perhaps some of Ely island. Its transition to the overlying conglomerate is about as obscure as that from the massive greenstones to the fragmental, or from the Saganaga Lake granite to the overlying conglomerate.

On the "burnt forties," which lie immediately southward from the above described ridge, are extensive outcrops of jaspilyte, and by reason of the profound folding to

causal relation to the boulder forms of which the rock consists, nor any relation to the other schistose wavy planes that surround such blocks.

2. The microscopic characters detailed (on page 15 of the paper of Messrs. Smyth and Finlay) apply to the pebbles of the conglomerate, but not to the matrix in which they lie, and have no bearing on the subject to which the authors apply them (page 16), *i. e.*, whether the rock as a whole is water-deposited, for a water-deposited pebble would probably retain the microscopic structures of its parent rock.

3. The so-called "irruptive contacts" which the authors depend on to prove the intrusive nature of the graywacke ("quartz-porphyry") are, at least many of them, fracture contacts, produced by the great crumpling and thrusting over each other which the strata have suffered. This kind of contact was once appealed to to prove the irruptive nature of the jaspilyte, and the writer showed that the same kind of evidence, perfectly exemplified on sec. 20, T. 62–15, would also prove the igneous nature of the graywackes and argillytes, the most unquestionably bedded and sedimentary of all the deposits of the region (*Fifteenth Annual Report*, pp. 234–243).

4. The authors make a distinction between two rocks; one is called fragmental and, being coarse grained, is presumed to "belong to a lower horizon than the other sedimentary rocks within our area"; and the other, a "granite porphyry" and one of the phases of their supposed irruptive quartz-porphyry. The former is found "at the point north of Mrs. Ackley's boat-house, in Tower, in S. W. ¼ S. E. ¼ sec. 30," *i. e.*, on Hoodoo point. The other is at the extremity of the point in section 20, already mentioned, and is thought to be a belt of quartz-porphyry that cuts the jaspilyte of the vicinity. Really, so far as the writer can judge by field evidence, these rocks are the same, with the exception that one is finer than the other and contains very few evident pebbles of quartz-porphyry. The coarser one is as plainly a part of the conglomerate as any of the outcrops on that peninsula, and is represented by rocks Nos. 2012 and 2013.

5. The authors fail to notice the distinctions between the two greenstones, *i. e.*, between that of the mines, which is intimately associated with the jaspilyte (whether irruptive or fragmental need not be considered), and that which is later and certainly fragmental, and which serves as matrix for the basal conglomerate.

6. They likewise fail to note the distinctions between the intrusive dikes of quartz-porphyry and a recomposed debris of quartz-porphyry—a graywacke—and have classed them all as one and supposed they are all intrusives cutting the iron formation. There may be both acid and basic old intrusives in the region, especially the former, but they should be kept distinct from the debris that results from their disintegration.

7. The descriptions, so far as they can be understood, apparently confound two slates, viz., that which is a dependency of the jaspilyte, a dark, nearly black, siliceous slate, passing to chert, of the age of the jaspilyte, and that which is an argillyte and associated intimately with the graywackes that belong both above and below the non-conformity.

8. They ascribe to the writer various notions which he never entertained, viz., that schistose structure is "proof of sedimentation" (page 5), that he never considered the idea "that the schist might be irruptive" (page 7), and that the Lee hill is "separated from the Soudan hill by a fault involving a heave of about one mile" (page 7).

which the locality has been subjected the Stuntz conglomerate and some of its finer phases have been brought into abrupt contact with this original jaspilyte, both parallel and perpendicular to the general strike, a relation which might be mistaken, as has been done by Messrs. Smyth and Finlay, for an example of intrusion of one rock upon the other.

This occurrence of quartz-porphyry in the Lower Keewatin is a repetition of what may be seen in Lake county, in the region westward and southwestward from Snowbank lake, where it occupies extensive areas, and geographically lies between the oldest massive greenstones and their overlying conglomerate, and a series of later greenstones which contain jaspilyte iron ore.

The granites and the Archean revolution. The evidence is not altogether satisfactory as to the relative date of the intrusion of the granites in the northern part of this area, and the metamorphism of the clastics which accompanied it, *i. e.*, whether this revolution followed or preceded the Upper Keewatin. The subject has not been investigated in the field since the recognition of the separateness of the Upper Keewatin from the Lower. The crystalline schists that are found in the northern part of Vermilion lake come on gradually by a metamorphism which increases in degree toward the north, the unaltered schists being such as prevail largely about Vermilion lake, so far as can be distinguished, and apparently conformable with the slates and graywackes of the Upper Keewatin. They are, however, in general more schistose than the Upper Keewatin, and resemble those schists which in other places, as north of White Iron lake, and north of Long lake, are changed in the same manner by the granitic intrusion and become the crystalline schists of those places, and these are of the Lower Keewatin. The probability is therefore that the granitic intrusion in the northwestern part of Vermilion lake took place before the accumulation of the Stuntz conglomerate, and that it was the prime cause, in a dynamic sense, which separated the Keewatin into two parts.

About Moose, Snowbank and Disappointment lakes, the granitic revolution was after the formation of the Ogishke conglomerate, and that conglomerate is converted into the mica schists of that region.

There are apparently three epochs of granitic intrusion, and one of quartz-porphyry. There are various places where quartz-porphyry dikes penetrated the Archean prior to the Archean revolution, and these intrusions gave origin to the materials of the Stuntz conglomerate, already described, which lies non-conformably on the Lower Keewatin. Two sets of granitic dikes cut the one the other, and they are apparently later than a third set which rise into prominence and are visible further north. Irrespective of this there are certainly two sets of granitic dikes cutting the mica schists, etc., in the northwestern part of Vermilion lake.

The relations of these acid intrusives to the basic and to each other can be seen on sec. 36, T. 63–17, opposite Avis island. The earliest seems to be one of the sets of basic dikes (No. 1985). This is cut by granitic dikes, one set of which cuts the other. The earlier one of these is represented by rock No. 1983, and the later by rock No. 1984. The latest, as observed at this point, is rock No. 1982, while the mica schist itself is No. 1981. Besides these distinct cases of sequence, showing greenstone both older and later than the granite, there are also mixed conditions in which there seem to be inclusions of acid rock that stain the greenstone. There is sometimes great confusion of structure, but in all cases the different rocks (greenstone, granite and schist) can be identified.

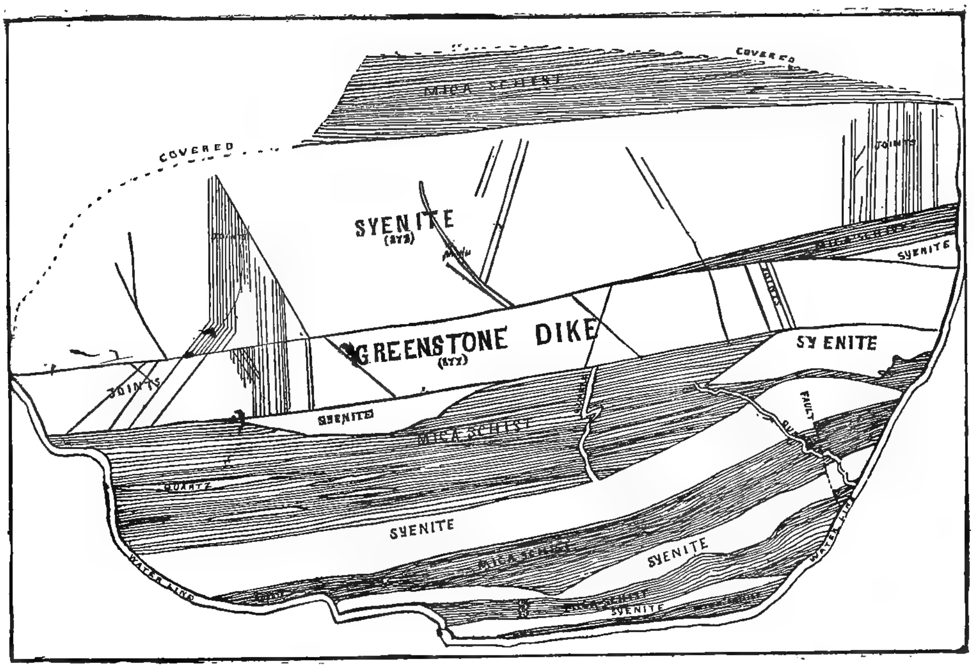


FIG. 105. SEQUENCE OF GRANITE AND GREENSTONE DIKES, MENAN ISLAND.

On Menan island where the relations of these dikes to each other were sketched in 1886,* the above figure shows the general structure. There are two granites. One is cut by a straggling dike from the other. The older is rock No. 1986 and the younger No. 1987. In thin section they do not show any noteworthy petrographic differences, but the older one appears in the field finer grained and whiter than the younger, which is reddish. This same younger straggling dike continues on through some of the mica schist, directly into contact with the great greenstone dike to No. 877, and there is cut off by the greenstone dike, which shows two epochs of granitic intrusion, one cutting the other, previous to the greenstone dike No. 877. At another place on this surface an older greenstone is cut by the red granite No. 1987. This greenstone is rock No. 1989. For more definite description of these rocks the

* *Fifteenth Annual Report*, p. 289.

reader must consult the corresponding numbers of the chapter devoted to the petrographic geology in vol. v.

At a point a little further north, on Menan island, is a gray rock (No. 1990) fine-grained, six inches wide, cutting granite (apparently the younger granite), which is cut by a still later greenstone. Rock No. 1990 also cuts this later greenstone. When a greenstone dike cuts the granite it is apt to become schistose, especially if it runs in the direction of the prevailing schistosity.

On the east side of the channel, where the route runs north, at N. W. ¼ S. E. ¼ sec. 26, T. 63–7, is a rock (No. 1991) that is supposed to be of the same nature as No. 1990, the youngest of the eruptive rocks of the region, which appears in the form of a spreading laccolith, or irregular mass, in the midst of the schists and granites, forming the highest part of a knob a little back from the lake. This rock is fine-grained and gray, and is evidently an important irruptive of the Archean. It is also penetrated by a coarse, pegmatitic vein-like granite much lighter colored (No. 1992).

Which one of these granitic intrusions, or whether all of them, can be connected with the series of granitic dikes that characterize the transition belt, *i. e.* the change from mica schist to gneiss and to granite, which supervenes still further north, it is not yet possible to state. But it is probable that rocks Nos. 1991–1993 are connected with that great intrusion, and that the other intrusions were earlier.

Allusion has already been made to the acid and basic dikes of the region, and to the probability that the youngest series of the acid dikes is the southern representative of the great granitic intrusion, which also penetrates the schists in the manner of dikes. Indeed, the dikes that begin to appear on the shores of Birch bay and on Menan and Avis islands increase in number toward the north, and finally merge into a great granitic area, replacing the schists entirely, the schists becoming gradually more gneissose, until they become a pronounced gneiss with parallel sedimentary banding in the same direction as that of the schists. It seems, therefore, from all the evidence at hand, that the great revolution which produced the granites and gneisses which extend across the northern portion of this area, was the epoch of generation of the latest of the crystalline rocks of the Archean of this plate, and that these rocks, instead of being placed at the bottom of the Archean, belong at the top of the Lower Keewatin.

These rocks are generally not sheared. The granite rises in domes and hills, and sometimes produces a rugged country, but it is not much more elevated than the areas of the schists. It may have been originally much higher, but, if so, the decay of all post-Archean time, the base-leveling action of the erosive agents of the atmosphere, and especially the abrasion of the glacial epochs, have removed the principal elevations and reduced the country, in the main, to a comparatively uniform

plateau, with undulations usually of less than a hundred feet between the valleys and the hills.

The rock varies from coarse to fine grained, and from nearly white to red. It is quite likely that within the general area are patches of massive rocks of different Archean dates, preceding the epoch of the general revolution, and that some of these variations are due to difference of date and of genesis, but none of these distinctions have been followed out in the field. The whole region is a forbidding granitic waste, and but little time has been spent on it.

The samples that have been examined carefully are the following: Nos. 1990, 1991, 1992, 1993, 1994, 1996½. These examinations are yet to be made: Granites, Nos. 924, 927, 932, 936, 940, 941, 942, 943, 944. The details of the petrographic characters will be found in another chapter. In general, it is necessary here only to call attention to a feature presented by the feldspars of these granites, viz.: that they are frequently very much altered and very fresh in the same rock. In the case of the altered feldspars the alteration is greatest at the centre, which is the reverse of an alteration produced in a feldspar by weathering. In general, the rock of these granites is unsheared and unbroken by pressure; the fresh feldspars being secondary growths produced by a thorough recrystallization of an old rock *in situ* with easy access of moisture. The old feldspars are sometimes plagioclase and much of the new growth consists of microcline. The quartz is wholly fresh, and dates from the generation of the microcline.

With the granites are here included all those gneisses that are essentially homogeneous, and which were probably also of irruptive origin. They differ from the massive homogeneous granites in having parallel separation planes without mineralogical variation.*

The crystalline schists and gneisses (Coutchiching). This series of rocks, especially the mica schists, have been called Coutchiching by Mr. A. C. Lawson, under the supposition that they held a definite stratigraphic position. About the same time, but a little later, they were named Vermilion by the writer, who included in them the dark hornblendic gneisses, diorytes and schists which are usually developed in close association with the mica schists. The earlier term was adopted by the Minnesota survey under the "rule of priority," and it has appeared in all later reports. There is, however, no certainty and but little probability, that the mica schists described by Lawson at Rainy lake are of the same date, as sediments, as those of Vermilion lake, although it is highly probable that they were metamorphosed at the same date, at least at the same general epoch.

An enormous thickness of rocks had accumulated prior to this revolution, and they had been invaded by separate epochs of minor irruption. Such epochs resulted

*No. 6 of figure 1, *Twentieth Annual Report*, p. 16, 1891.

in dikes, both basic and acid, as has already been mentioned, and it is probable that many sills and laccoliths existed between the strata even before they were upheaved and folded. It is more probable, however, that the epochs of folding and faulting were also the epochs of the principal intrusions. The dikes must have been the feeders for the formation of surface effusive rocks, and perhaps for the support of Archean volcanoes. The crystalline schists, therefore, were likely to exhibit a varied composition and structure. Some old basic irruptives, as well as eruptives, under the pressure, shearing and metamorphism of the Archean revolution, already perhaps greatly decayed, were converted into hornblendic schists. The acid dikes of granite and quartz-porphyry were changed to crystalline rocks of indefinite characters—mainly to gneisses—while the graywackes, argillytes and quartzytes were permeated with an internal crystallization, by reason of which was produced the great body of the mica schist belt and many gneisses.

Now, while the seat and acme of this metamorphism was necessarily in the deeper parts of the older sediments and older portions of the crust, it is obvious that it might break out among the later ones, and that for large areas it might involve some of the superficial strata, or the strata last formed, and hence that the mica schists may be modifications of strata of different ages, and it is equally obvious that large tracts of the earliest rocks might not be invaded at all; and, there having been in the region no later similar convulsion, such exempted strata would come down to us nearly in the condition in which they were formed, barring only the changes that are incident to atmospheric decay, and to the pressures and foldings of later geological history.

There are a great many places where the transition from the schists to the gneiss can be observed more or less favorably. Indeed, as the drift proper is generally scant or wanting, this transition can be observed all along the boundary line as represented in this plate. The difficulties to continuous inspection arise chiefly from soil, vegetation, water and later debris. A very favorable place for examining this interesting transition is the west side of Outlet bay, on the dull point which embraces the corners of sections 14, 15 22 and 23.

On the point near the centre of sec. 14, T. 63–17, the rock is partly a breccia. This round point has three exposures; the northern one is this breccia, with no direction of dip or strike. At the next, toward the south, the rock is gneiss, or hard, closely jointed mica schist, or micaceous quartzyte, with a strike east and west, and nearly vertical, or dipping north. At the third the rock is evidently a bedded one, with little disturbance. It varies from a hard gneissic mica schist to a fine, hard, almost flinty, gray, micaceous quartzyte, with a dip of 35° to 40° toward the north. This is rock No. 879. These exposures are all small, from twenty feet to fifty feet

along the beach, and do not show their relations to each other by direct contact; but the dip seen in the last mentioned would indicate that it lies lower than the other two.

Still further south, about one-fourth mile north of the south side of sec. 14, T. 63–17, is a sharp, rocky point, projecting east, made up of mica schist and conformable layers of gneissic mica schist, and some syenyte dikes running in the same direction, all showing a very evident dip north (exactly) of about 40° from the horizon. In this are not only large conformable (or nearly conformable) layers, or dikes, of syenyte, but also small isolated and lenticular nests or nodules of syenyte (No. 880). These latter swell out so as to interfere with the foliation, which here is the bedding structure. It is very evident here that *a bedding structure is the cause of, and is converted into*, the foliation, producing a gneissic structure. Both can be seen in the same rock mass. This transition is discussed more fully in the chapter on structural geology,* in vol. v.

As to the nature and structure of the mica schists, the details will also be found in vol. v. The principal minerals are quartz, mica and feldspar with accessory amounts of garnet, hematite and magnetite. These are all of secondary origin in their present forms, although the elements of which they are composed are supposed to have existed in the strata originally in about the same proportions in the clastic debris derived from the abrasion of older rocks, not now identifiable, and from volcanic ejection. There is often an appreciable amount of hornblende, and this sometimes becomes abundant, and thus these schists pass to a hornblendic schist. It is probable that this is an index of the variable amount of volcanic basic debris in the original sediments, or of basic massive irruptives intermingled with them prior to their metamorphism. The feldspar grains seen in these schists, as well as in some of the schists not distinctively known as mica schists, are often difficult to distinguish from quartz, especially in thin section by microscopical observation. They are glassy and free from cleavage or structure of any kind. If the precaution be taken to examine the section in convergent light for the interference figure, it will be seen that the curved dark bars, and sometimes both hyperbolas of a bisectrix, characteristic of biaxial crystals, cross the field from quadrant to quadrant instead of the straight bars characteristic of quartz.† Such feldspars are of secondary origin, and they are sometimes seen in the same section with old feldspars, with which they present a striking contrast. In other cases the feldspars, though second-

*See also N. H. WINCHELL. Some new features in the geology of northeastern Minnesota. *Amer. Geol.*, vol. xx, pp. 41-51.

†The so-called "straight" bars characteristic of quartz when cut obliquely to the optic axis, are straight under the microscope only when the section is nearly perpendicular to the axis. As the obliquity increases these bars are curved as they enter the field and as they leave it, being straight only when they cross the centre of the field, in exact coincidence with the principal axis of one of the nicols. The dark bars of the feldspars are always curved. The quartz dark bar, moreover, can be distinguished from that of the feldspar by the fact that the former when curved has one end in the vertical or horizontal diameter. On rotation it swings into agreement with one or the other of these diameters, and on further rotation it passes through the diameter and curves in the opposite direction; whereas the latter crosses the field obliquely as a continuously curved bar, coming into one quadrant and leaving the field in the opposite one, never coinciding with either the vertical or the horizontal diameter.

ary, are cloudy apparently because of the inclusion of impurities rejected by the other minerals in the process of recrystallization.

The Lower Keewatin. The fundamental complex, or the congeries from which the mica schists represented on this plate were developed, was, as already intimated, a mass that embraced a great variety of sedimentary and massive rocks, although throughout much of it no distinctly fragmental grains can now be detected. The existing structures are but modified conditions of original structures. It is the problem of the geologist to interpret these modified structures, and in that way to discover the nature of the forces which operated to form their original structures, and again of those that gathered the rocks at the commencement. This inquiry cannot be entered upon here. At this place will be given only a concise description of the rocks as a whole, with reference to other chapters for many details, and for theoretical conclusions.

The principal rocks are "greenstones," massive and fragmental greenwackes; basic dikes of two or more dates; quartz-porphyries, graywackes and quartz-porphyry dikes; granites and granitic dikes; argillytes, black siliceous slates, jaspilyte and iron ores; quartzytes, conglomerates and limestones; mica and hornblende schists and dioryte.

The popular impression is that these rocks present an inextricable knot, a confusion of structure and of composition, and that it is useless to attempt to unravel it. Such, however, it does not appear to the writer. The progress of the survey over the most of the area of these rocks has been rapid, and, sharing in the foregoing belief and lacking sufficient time, but little effort has been made by the agents of the survey to differentiate these rocks chronologically in the field. Still, as the facts are collated, certain leading principles have been found out, and some idea of a sequence of structure can be expressed. This is the result of adjusting all the observations of the survey made by all its field-parties into a systematic scheme, supported by microscopical examinations of the rocks collected. It will be observed that in the foregoing enumeration of the rocks of the fundamental complex are included the granites, diorytes and gneisses and the mica schists of the Archean revolution, but they are the results (not the causes) of that revolution, and as rocks they are of later date than the rocks here considered. Not all of the above mentioned rocks occur within this area.

The oldest rock which has been detected by the Minnesota survey is a massive greenstone. It is not known to exist in the area represented by this plate, but it may occur in that portion which has not been well explored and is drift-covered, lying between Vermilion lake and the Giant's range, and it is not certainly to be excluded from the ridges which at Tower hold the iron ore lodes, and which extend eastward to Ely.

As a derivative of this is the greenstone which is seen closely connected with the jaspilyte, which appears to be of fragmental origin, either as detritus or as volcanic ash, or as both. This becomes conglomeratic and agglomeratic, and its thinnest sheets are interstratified, at the mines, with the jaspilyte, and such interstratification is subject to the various parallel tortuosities of the jaspilyte itself.* This rock under such conditions has essentially a sedimentary structure, and as a sedimentary rock it blends with the siliceous strata that carry the ores of the region, and is interchangeable with them. This fragmental greenstone becomes aphanitic, and somewhat siliceous, and also, when still more plainly sedimentary, and siliceous, it forms green stratified rocks which are above designated *greenwackes*, and at other times it forms a greenish flint. With still further addition of more coarse acid material it passes to graywackes or to argillytes. For the formation of these acid rocks, however, it is evident that there must have been a source of acid material. There must have been, therefore, either chemical precipitation of silica or detrital distribution of acid debris, and perhaps both. There are reasons for believing that the chemical precipitation of silica and probably alkaline silicates prevailed for a long period of time prior to the extrusion of any acid eruptives. The earliest sedimentary acid rocks known are the jaspilytes and they consist essentially of chemically deposited silica and hematite, while the fragmental greenstones that embrace the jaspilytes are cut, according to Smyth and Finlay, by the earliest known acid eruptives, viz.: by quartz-porphyries. In Lake county, however, is a large mass of quartz-porphyry, lower in the series than the jaspilytes, and it may be demonstrated by later examination that all the Archean quartz-porphyry originated at a date anterior to the jaspilytes. The apparently igneous contacts of the quartz-porphyry and the Stuntz conglomerate on the jaspilyte on the "burnt forties" near Tower are believed to be due to folding and mechanical displacement.

After the sediments had acquired a strong siliceous ingredient, both chemical and fragmental, it is evident that acid lands were formed by upheaval of acid masses. Such upheavals or extrusions may have been separated by long intervals of time, and may have been very numerous, but within the area of this plate but three can be affirmed which occurred within Archean time. All these acid igneous rocks, however, are, so far as known, of later date than the Keewatin basic ones, with the possible exception of the quartz-porphyry.

There were many alternations of these rocks (the graywackes and the greenwackes) and many alternations in the nature of the irruptives that invaded them, and that were interleaved with them, but for the most part, they are still easily distin-

*It might be repeated here that this "greenstone" is not that which, as a schist, embraces fragments, large and small, of the jaspilyte, as on the south ridge (figure 2, plate WW), but it refers to that interstratification which is exhibited occasionally on the north ridge, and which is represented by the photograph (figure 1, plate WW).

guished, one from the other. It is only when the derivative is essentially and necessarily similar to its parent rock, and these are found in contiguity, that it is difficult to distinguish a hand sample of one from one of the other.

Aside from the great metamorphism which accompanied the Archean revolution, as described above, there is no chemical change or series of chemical changes worthy of note that have passed over these rocks which have rendered alike unlike rocks, nor *vice versa*. The debris from the basic irruptives is still basic debris, and the detritus from the acid is still acid, and, when circumstances of later history have not been unfavorable, they still retain their evident sedimentary structures. When these have been obscured by dynamic forces, and the rocks have been given a schistose structure, there is at transition points great difficulty in distinguishing the fragmental from the massive, for this has produced a recrystallization in both, bringing them into greater similarity.

Nomenclature. There are several epochs in the history of the fundamental complex which might be distinguished by special geological terms, and it might add to the elucidation and the preservation of the steps of that history to apply such designations. At present, however, it is only necessary to call attention to the term *Kawishiwin*, which was given by the writer, in 1888,* to the greenstones, which above are stated to embrace the iron ores, and to their massive associates, which together extend from the mines at Tower to and beyond Ely, and spread over the region of the Kawishiwi river. They can be traced, indeed, continuously from the vicinity of Tower to Gunflint lake, where they pass below the Animikie. When this name was applied, it was said to designate the latest rocks of the Archean, with the assumption that the gneisses and granites of the northern part of Vermilion lake were at the bottom of the series. At that date the rocks of the fundamental complex had not been much examined, and the prevalent notion that those to which the term Laurentian had uniformly been applied lay below all the rest was accepted. But any statement of the order of genesis of these rocks, so far as they occur in Minnesota, made at that date, has to be reversed, and the greenstone terrane, or the Kawishiwin, is now known to contain the oldest known rocks in the state. With this qualification it is proposed to continue the use of this term, and to include in it both massive and fragmental portions of the greenstones of the Lower Keewatin.

This result has an important bearing on the structural relations of the rocks of the Vermilion Lake plate. It reveals at once the general order of succession of the strata, for the strata become younger and younger at the surface, on receding from the Kawishiwin.

The iron ores of the Vermilion range. A great many details of the structural relations of these iron ores to the enclosing rocks have been given in the earlier

*Compare *Seventeenth Report*, pp. 39–42; *Amer. Geol.*, ix, pp. 359–368.

reports of the survey.* These were published with a view to show the complexity of those relations, and as data for the drawing of inferences as to the origin of the ores, and the date thereof. They need not be repeated in full. Only a summary of these relations will here be given.

1. The first and most fundamental fact connected with the Vermilion hematites is their occurrence in a "greenstone." This is not a massive crystalline rock, but one that is fine-grained, indistinct, and often grades by sedimentary structures into a more and more siliceous rock, the silica being of the same compactly and finely granular kind as that which is the chief impurity of the ore. This greenstone as it is interbanded with the ore is seen to be the same as that which is interbanded, by sedimentation, with certain argillytes. In numerous such cases the iron element is wanting, and there results a greenish flint, or a flinty argillyte with beautiful sedimentary banding. Indeed there are sedimentary alternations and variations of almost all kinds between these leading elements, greenstone debris, argillyte, fine silica, iron ore, constituting, as one or the other predominates, a jaspilyte, a siliceous argillyte, a siliceous greenwacke, an ordinary fragmental greenstone, a green flint, a ferruginous banded argillyte, and in one instance at a higher horizon (plate X) a conglomeratic jaspilyte in which the pebbles are of red granite and other kinds of foreign rock. The facts go to show that the iron ore was accumulated in the ocean, for its larger structures and its associates all owe their essential features to sedimentary action. These variations are not all visible at the mines, nor indeed do they all occur at any one place, but they are to be observed on taking an extended survey, and by noting carefully, at different and often distant localities, the transitions that the ore deposits experience. The mines are opened in the best ore deposits, and that fact precludes the mining excavations from revealing these gradations to worthless ore and to rock and other associations of the jaspilitic silica. Still, even at Tower, some of these alternations between the ore and the greenstone are plainly exposed.

2. If it be admitted that the structures and associations of the ore (*i. e.* the hematite and the quartz) require that they were accumulated in the ocean, it is equally imperative to admit that these elements do not show any clastic characters as minerals. They do not seem to have been detrital debris. They are as a class exceedingly fine and wholly crystalline, though closely banded together in what appears to be a sedimentary structure. There is no known method of origin for such elements, so associated with oceanic water and with each other, except that of chemical precipitation. Hence the ore and the silica must have been in solution in the ocean, and it was by the occasional mingling of fragmental materials with the

* *Fifteenth* and *Eighteenth Annual Reports*, and *Bulletin vi.*

chemical precipitates that the jaspilyte is caused to grade into flinty argillyte or into siliceous greenstone.

3. If we look for the cause of these precipitations during the accumulation of the fragmental portion of the Kawishiwin, it is necessary to recall the probably volcanic character of the epoch in which they were formed. They follow directly after the earliest of the greenstones which sometimes still reveal a massive and crystalline structure, showing that they resulted from the cooling of a molten basic magma. The later greenstone is frequently a volcanic tuff. The ore occurs in this later greenstone. The ejections of volcanoes must have disturbed the equilibrium of the oceanic solutions, and it is plain that amongst the first and the most copious of the precipitates would be hydrous ferric oxide, and hydrous silica. These would accumulate in strata on the bottom of the shallow ocean in the neighborhood of the Archean volcanoes. The lapse of time has expelled the chemical water from each and has allowed the complete crystallization of both in the forms that they now exhibit. The rocks have all been upheaved and set on edge since their formation, and by pressure and shearing the ore lenses have been modified in shape and folded and fractured so as to bring them into present contact with rocks to which, sometimes, they have no genetic nor chronologic relation.

While the foregoing outlines the origin and history of the Vermilion ores, it will be well here to state, further, that this history, so far as it relates to their origin, is wholly within the Lower Keewatin. Between the Lower and Upper Keewatin occurred a revolution which is now expressed by a great conglomerate at the bottom of the Upper Keewatin (the Stuntz conglomerate at Vermilion lake) and the rocks of the Lower Keewatin all contributed to the composition of that basal conglomerate. Hence the jaspilyte, sometimes in large masses, as seen in the south (or Lee) ridge at Tower, and very frequently in the form of pebbles and as sand, going into the composition of some of the Upper Keewatin schists and graywackes, is abundantly disseminated as clastic debris amongst the later rocks. This fact has not always been recognized, but all the jaspilyte, whether original or clastic, has been considered as one in date and origin. This mistake was made in Bulletin vi of the survey, where the reader will find a more elaborate discussion of the origin of the Vermilion ores. These two forms of jaspilyte are shown in figures 1 and 2 of plate WW.

It should also be stated, further, that even since the formation of the Upper Keewatin profound fracturing and folding have taken place, and that sometimes the Upper and Lower Keewatin are folded together and so fractured and displaced that large masses of the one are brought incongruously into contact with the other. On the "burnt forties," so-called, situated northeastwardly from Soudan, may be seen, as already explained, a good illustration of this profound folding. Here are

Lower Keewatin greenstone and jaspilyte brought into contact with Upper Keewatin conglomerate, both standing nearly or quite vertical. The lines of fracture and folding mainly run about east and west, but some of them are transverse. The complication here is still further increased by the occurrence of a series of later diabase dikes which have cut both Upper and Lower Keewatin, probably of the same date as those of Stuntz island (plate SS, figure 1).

There is therefore no need to appeal to any secondary cause for the origin of these ores; they are original in their present form, and native in the rocks in which they lie, and have suffered as little alteration since their generation as any of the Archean rocks; probably less, owing to their intractable nature, than the Archean granites and greenstones. Occasionally there are secondary deposits of limonite and siderite, and the latter is seen in rare instances to penetrate sparsely within the ores; but in all cases the microscopical form and relations of the grains show unmistakably that the siderite is a secondary product and not an original one. Its crystal rhombs lie in the flinty jaspilyte in the same manner as pyrite cubes sometimes exist in argillitic slates.

For the special characters of the rocks of this area reference may be made to the following numbers in the petrographic chapter of vol. v:

Rocks of the series of N. H. Winchell: Nos. 379-432; 864-947; 1449-1452; 1502-1509; 1546-1572; 1957-1965; 2270-2272.

Rocks of the series of A. Winchell: Nos. 989W-990W.

Rocks of H. V. Winchell: Nos. 1H-20H; 286H-305H; 333H-357H.

Rocks of the series of U. S. Grant: Nos. 278G-298G; 1010G-1016G.

Rocks of the series of J. E. Spurr: Nos. 181S-184S.

CHAPTER XXX.

THE GEOLOGY OF THE CARLTON PLATE.

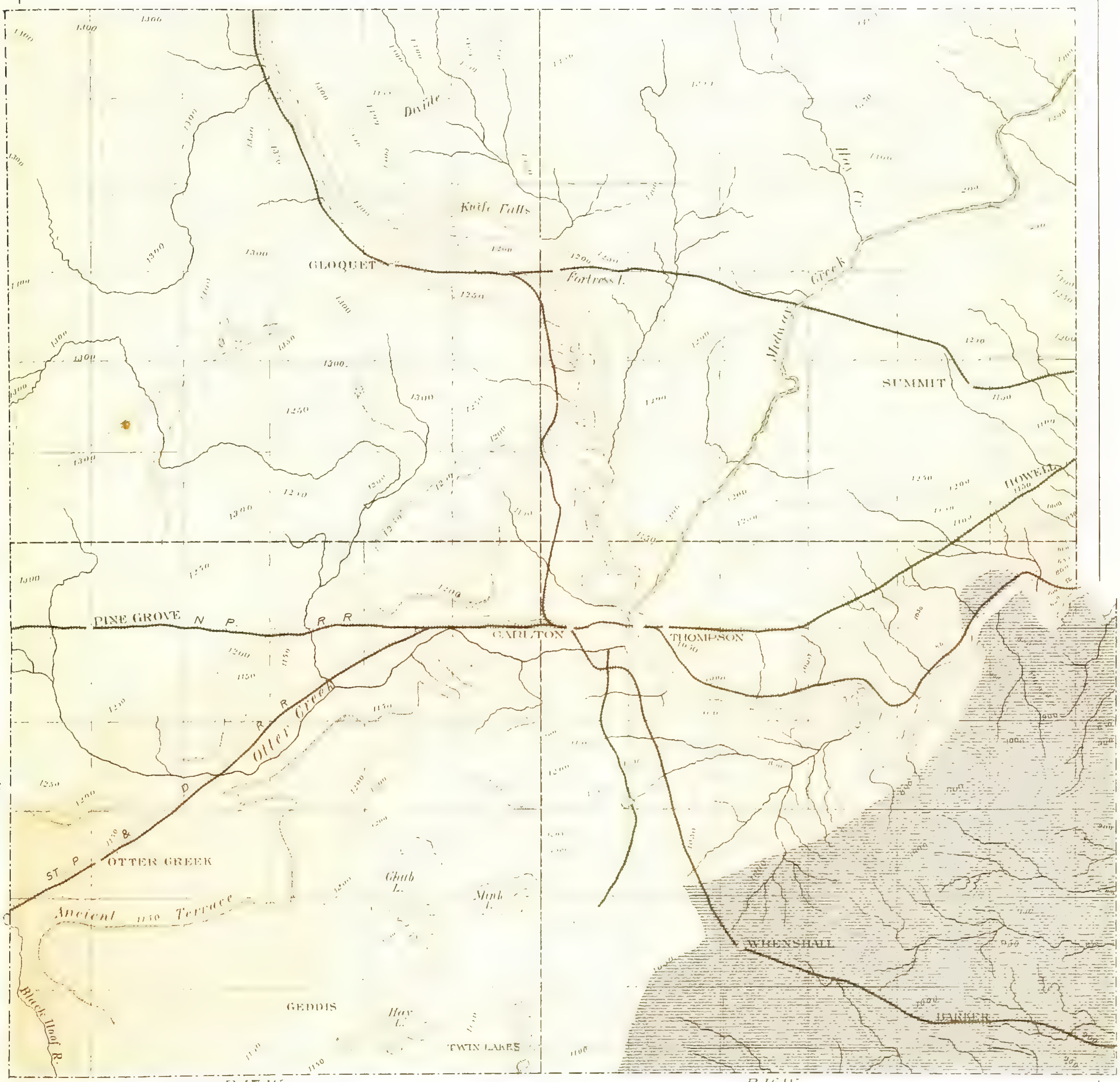
(PLATE 87.)

BY N. H. WINCHELL.

A general description of the geology of Carlton county has been given in connection with the Carlton County plate (No. 56). In this chapter will be mentioned some facts of geological interest of a more detailed nature which were observed in the immediate vicinity of Carlton, and the age of the Thomson slates will be discussed.

The area included in plate 87 is a very interesting and important one, scientifically and prospectively. The former presence of lake Superior at this elevation, and the still earlier course of the St. Louis southwestwardly, and the subsequent drainage of the lake to a lower level, with a change in the course of the St. Louis, have conspired to bring into prominence various geologic and topographic features within a small compass.

From Cloquet the St. Louis formerly spread widely over the country to the south, and probably occupied the channel that passes through secs. 23, 26 and 35, T. 48–17. It then reached the Moose Lake valley by way of the Otter Creek valley, and that in which the St. Paul and Duluth railroad runs between Otter Creek station and Mahtowa. At a little later date it descended by way of its present channel, southward from Cloquet, spreading over the boulder-paved plain that borders the river on the west, on which the St. Paul and Duluth railroad is located, to Carlton, where it spread more widely, forming a lake-like expanse (glacial lake St. Louis) that extended southwestward and found its outlet by way of the Otter creek and the upper Black Hoof valleys, reaching the Moose valley near Barnum. Still later the level of the waters was again lowered by the opening of a channel from the Nemidji valley into the Portage valley. The Nemidji stage of the ancient lake Superior, which existed while this ancient channel was occupied, was about 1070 to 1080 feet above sea level, and as Carlton is at 1083 feet, the old beach line was probably in the near vicinity. We may assume, at least, that the most of the St. Louis valley below Carlton was yet under lake Superior, and that the rocks that now form the many



GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA

CARLTON PLATE

BY N. H. WINCHELL

Explanation

Glacial

Potsdam

cascades and waterfalls between Thomson and Fond du Lac were also covered by the drift sheet, secure from abrasion either by the lake or by the river. The lake was successively lowered by finding lower outlets till it finally reached its present level. Thus by degrees the St. Louis river excavated its present channel below Thomson through the drift, leaving as its latest records the precipitous clay cliffs that outline it most of the way to Fond du Lac, for its erosive effect on the slates below Thomson are almost imperceptible.

The Thompson slates—their probable age. These slates were first examined in 1877,* and in the report for that year is a description of their cleavage, joints, dip and manner of outcrop, with illustrations. They were thought then to be the same as those which occur at Little Falls, on the Mississippi, below Brainerd, "but it here shows none of the concretionary hornblende, or dioritic rock seen at Little Falls, and taken all together, is somewhat finer grained, not showing an evidently micaceous composition." The relations of these slates to similar rocks in the northeastern part of Minnesota were not referred to at that time.

In 1883, on the occasion of an excursion from the American Association for the Advancement of Science, from Minneapolis, these slates were examined by a number of geologists, including Dr. T. Sterry Hunt. At this time were noticed the peculiar limy lumps or "concretions," and subsequently Dr. Hunt, with the concurrence of Dr. J. W. Dawson, reported evidences of a "keratose sponge" in these limy masses.†

In 1890, the writer, after a more careful examination of these rocks in the field,‡ made for the purpose of arriving at a conclusion as to the age of the formation, was satisfied that they are of the Animikie, and of Taconic age. At a later date this opinion was held with much less confidence, and when, in an extended review of the subject by Mr. J. E. Spurr,§ the evidence seemed to preponderate against the Animikie age, it was entirely abandoned in favor of the view urged by Mr. Spurr, viz., that these rocks belong to the Keewatin. It was with this belief in mind that further examination was made in 1893 and 1894, when the various field observations and final comparisons of the rocks of the county with surrounding terranes led to their separation into two series, one of which is probably of the age of the Taconic, and the other of the Archean, the latter representing probably both Keewatin and Coutchiching. At what point these can be geographically separated, it cannot be shown, because of the abundant drift. It can only be said that the outcrops extending from Cloquet to Carlton and Thomson, and thence southwestward to the vicinity of Otter Creek station are believed to be a part of the Animikie, and that the slates and schists that occur at Barnum and Moose Lake, and westward from Mahtowa, as well

*These slates were examined in 1877, by E. T. Sweet. His report thereon is published in *Geol. of Wis.*, vol. iii, p. 334, 1880.
† *Trans. Roy. Soc. Canada*, vol. i, sec. iv, p. 250.
‡ *Twentieth Annual Report*, p. 29.
§ *Amer. Jour. of Sci.* (3), xlviii, p. 159.

as the outcrops in the valley of the Kettle river, and westward and southwestward into Pine county, are considered much older.

It has to be admitted, further, that, so far as observed, there is nothing in the general lithology of the Thomson slates, *i. e.*, in their average composition, their structure, dip, strike or metamorphic condition, which is diagnostic of the Animikie from the Upper Keewatin, as that part of the Keewatin appears about Tower, and that there is no *demonstration* of their Animikie age. The Thomson slates are isolated, but are surrounded, at distant points, by known outcrops whose geological age is reasonably well known. The best that can be done is to assign them to that age for which there is a preponderance of evidence. It is that preponderance which leads to the result above expressed.

Toward the west and southwest is an area of crystalline rock, with gneiss and granite. The schists on the Kettle river, and throughout the western part of the county, evidently are a part of the same general crystalline area. On the Kettle river they are mica schists. They are mica schists at one or two outcrops between the Kettle river and the Moose river at Barnum. In general, however, along the railroad at Barnum and Moose lake, they are less micaceous and resemble some of the graywackes and slates of the Upper Keewatin. However, westward from Mahtowa these rocks are decidedly like the Lower Keewatin, being greenish and highly chloritic, with irregularities that have an agglomeratic appearance, recalling the structures seen eastward from Tower and at Ely. These rocks, which have an older aspect, a more altered texture and have been subjected to dynamic action comparable to that of the Keewatin, are referable to the Archean. They may be grouped with the slates mentioned by Mr. Spurr as the most northern exposure of the rocks of the region,* seen in sec. 27, T. 51-19, and in general with the Keewatin and Coutchiching.

The outcrops, however, about Carlton, while not differing much from those at Moose lake and Barnum, nor very strikingly from those mentioned in sec. 27, T. 51-19, yet are believed to belong to the Animikie, for the following reasons:

1. They appear more recent, their bedded stratification is more perfect and continuous, accompanied by ripple and other water marks, and their structure is a distinct slatiness, without loss of sedimentary structure, instead of a schistosity in which a micaceous element is prevalent and in which the sedimentary banding is nearly or quite lost. Their dip is very observable and prevailingly toward the south.

2. They form the rim of the lake Superior basin, and lie in the line of strike of the Animikie and gabbro (of the Cabotian eruptives) which are associated, so far as known, all the way from Pigeon point to Duluth, thus serving to continue the known topographic and geognostic features of the Animikie.

*Spurr's report in the *Twenty-second Annual Report* of the survey, p. 121, for 1893.

3. They rise and fall in a series of southward dipping, mono-clinal, short ridges in a manner entirely comparable to those of the Animikie along the international boundary.

4. The Animikie is represented by the northward dipping rocks of the Penokee range, on the south side of the lake in Wisconsin, and in accordance with the well known early synclinal structure of the lake Superior basin there must have been a point where at the western end of the basin these strata passed round from north to south. It is an important and conspicuous formation, constituting on both sides of the basin the most marked elements in the topography, and it is not likely that they would be wholly concealed at the western extremity of the basin, and especially so when the rock is laid bare, as it is, by a large river (the St. Louis) across the rim of the basin at the point where they would naturally be expected to exist.

5. Like the Animikie at Thunder bay and at Pigeon point, they exhibit a peculiar calcareous feature, namely, limy lumps (No. 1607), which, originally gray and hardly distinguishable from the body of the rock when fresh, when weathered become very conspicuous. They turn dark, sometimes almost black, and spot the weathered surface. These spots weather away faster, and thus the surface is pitted with depressions. It is in these lumps that Dr. Hunt reported the existence of traces of a "keratose sponge." They are more fully described below. Such calcareous lumps are not known in the slates below the base of the Animikie. They evidently contain a considerable amount of carbonate of iron and are comparable to the calcareo-ferruginous irregular strata that have been described in the Animikie at Gunflint lake, where they are near the bottom of the formation, and by Mr. Spurr* at the west end of the Mesabi range, near Virginia. They are not always distributed at random as isolated spots or lumps, but they are governed somewhat by the stratification, and in rare instances they coalesce so as to constitute a more or less conformable stratum, and in one instance, at Carlton, they dwindled into a narrow streak, which ran for about thirty feet as a stratum in the banding of the sedimentary structure before it disappeared entirely. This similarity is perhaps the strongest bond uniting the Thomson slates with the Animikie.

The dip of the Thomson slate. In the reports that have been published the following readings of the dip of these rocks have been stated. To these observations are added those made in 1893 and 1894:

Ninth Report—

Page 12. General incline of the heavy beds, lowest falls, S. E. 63°.

Page 13. At the large rock island, east of Island No. 5; dip of the formation 27° S. E.

Page 13. Just above Island No. 6 slate dips S. 30° to S. S. E. 48°; crossed by a perpendicular cleavage.

Pages 14 and 15. Head of the island on S. E. ¼ sec. 9, T. 48–16. Here is an interesting irregularity. Appears horizontal, bends downward and even dips slightly north toward the river, then suddenly deflected

* *Bulletin* x, pp. 9–10.

upward, but returns to horizontality, again dipping into the river. This is probably a folding, though the general dip continues south. (A similar folding is observable in the railroad cut west from this place.)

Page 15. Near the centre of sec. 8, T. 48–16, at fall of twenty-two feet, 33½° S. S. W., swinging round to south-southeast, then being in a dip 39° to 43°.

Page 16. Slate hills in secs. 9 to 4, T. 48–16, dip 46½° to 60° S.

Page 16. In the gorge under the railroad bridge, Thomson, 46½° S.

Page 18. Carlton, S. W. ¼ sec. 6, T. 48–16; average dip 57° S., 5° E.

Page 20. Cloquet, 75° to 80° S.

Page 20. Much confusion and jointage, but after careful study the dip at Cloquet is made out satisfactorily to the south.

Page 21. On island first above Knife falls; dip N. 25° (?), forming an angle with slaty cleavage which dips S. 85°.

Page 22. Same island (correction of the last) 48° S., 3° E.

Page 22. Knife Falls, 48° S.

Page 25. Below Knife Falls, S. 60°.

Page 25. At Fortress island dip either coincides with the slaty cleavage (about vertical), or is 45° S. E.

Page 27. Cut on the Knife Falls railroad; sedimentary bedding is not discerned, perhaps vertical, coinciding with the cleavage.

Page 27. Near the drift bluffs on Knife Falls railroad N. 45°, and 80° N.

Page 27. Heavy bedding, dips south about 45°.

Page 28. About two and a half miles north from Carlton, quartzyte, with pebbles of slate, dips at high angles south, crossed by a coarse slatiness at about the same angle north.

Page 29. Along the east side of the Big island, near Thomson, river runs against the strike, the dip being 45° N.

TWENTIETH REPORT—

Page 29. Dietz & Dugan's slate quarry to Cloquet. Dips in opposite directions, showing several great anticlinals, the inclination being frequently 75° to 90°, and rarely less than 50°.

NOTES OF 1893—

Near the Cloquet depot, varies from a vertical to 78° about north.

S. E. ¼ S. E. ¼ sec. 9, T. 48–17, near the section line, S. 5° to 10°, 60° W.; two miles north of Otter creek station (crossing of Otter creek), rock cut here shows dip 20° N., faulted much.

NOTES OF 1894—

In the most easterly of the cuts on the railroad, southeast from Carlton, the strata show a conspicuous folding. The general dip of the whole is about 45° N. 10° W., varying to nearly vertical. The whole sweep of one anticlinal fold can be seen in the face of the cut. There are also synclinals (plate XX, figure 1).

Next cut toward the west, dip, 75° to 85° N.

Third and last cut, toward the west, dip, S. 45°.

At Knife falls. The whole rock formation here dips south about 45°, although toward the west of the falls on the south shore, there is an area in which the dip is northeast. The prevailing dip all about Cloquet is southerly, varying to south-southeast.

It appears, therefore, that there is a prevalent southerly dip at an angle that would average, probably, above 45°. At the same time it is plain that several folds exist, of which two important localities have been observed. There are several anticlinal folds visible at the slate quarry of Dietz and Dugan, extending from there to Cloquet. Another axis of a fold, pitching eastwardly, runs from the river at the head of the island on S. E. ¼ sec. 9, T. 48–16, westward to the point at which it crosses the railroad, where it is quite distinctly brought out in the cuts made for the railroad grade (plate XX, figure 1).

The calcareous nodules. These calcareous patches are one of the most singular and characteristic features of this rock. They cause dark spots and depressions on the weathered surfaces, sometimes eighteen by thirty-six inches in size, and they are found in the fine-grained and coarse-grained portions of the rock. They seem to be sporadically distributed, but it has been noticed that rarely they have a relation

FIG. 1. SHOWING FOLDING OF THE THOMSON SLATES, SOUTH-EAST FROM CARLTON. (pp. 554, 562.)

FIG. 2. RED CONGLOMERATE AND SANDSTONE INTERBEDDED, ST. LOUIS VALLEY, CONSISTING LARGELY OF ERUPTIVE DEBRIS, ST. LOUIS VALLEY. (p. 570.)

to the sedimentary banding. That is to say, over a large exposure on the Thomson slates they are more frequent in some layers than in others. Indeed, at one point within the limits of Carlton, north of the railroad, it was noted that they were so frequent in a narrow belt that they began to coalesce, and, while they also became smaller, they formed a continuous thin layer which extended visibly about thirty-three feet and pinched out. This rather indicates that they are a dependency of the sedimentation. These masses are in size from an inch or less to three feet long, of rounded outlines.

Several thin sections have been made in different directions through the structure (especially of rocks Nos. 1607, 1609 and 1611), but they show no organic forms or structures, so far as can be seen from the sections made. They consist essentially of calcite, which is usually compact-granular, sprinkled with more or less angular grains of quartz similar to the quartz grains in the graywackes and slates in which the lumps lie. But occasionally the calcite is in larger crystalline masses which have a roughly radial structure, having a black cross between crossed nicols. The rays are not single and thread-like, but rather spreading and plumose; and across them run the coarse calcite cleavages. These cleavages themselves are not straight, but are curved in such a manner that if they were continued long enough they would form circles about the common centre of the group.

A calcareous mass was found in the Animikie slates at the lake shore on the south side of the tongue that divides Pigeon bay into north and south arms (No. 1846). As it is in the form of septaria, more or less elongated in the direction of the sedimentary structure and presented some forms which might be organic, some fragments were submitted to Prof. G. F. Matthew, of St. John, New Brunswick, for examination, but in his judgment the structure is not organic, but probably due to an encroachment of a calcitic crystalline development between layers or filaments of detrital matter, resulting in a grouping that resembles that of cone-in-cone. Although it is composed of curiously disposed low conical bodies which together constitute a thin calcareous layer or several layers in the slates, they are probably wholly of mineral origin, caused by the accumulation of lime between the slates. Dr. A. C. Lawson collected similar pseudo-organic bodies from the Animikie in his work for the survey in 1891, and they were examined by Dr. Karl von Zittel at Washington,* in thin section, but were pronounced non-organic. These calcareous masses have in common one feature, viz., they take on a dark, rusty coating as they decay. They have not been seen associated with pyrite, and it is to be supposed therefore that the salt consists in part of carbonate of iron. Therefore they may be compared with the rusty carbonate of lime that is so freqently seen near the bottom

* On the occasion of the Washington meeting of the international congress of geologists.

of the Anmikie (?) in the region of Gunflint lake, where it constitutes quite a noticeable stratum, and contains numerous angular masses of flint and serves as a matrix for a loose breccia, being apparently a portion of the sedimentary beds of the Animikie.

Although, at Carlton, it embraces many fine angular grains of quartz, in some instances, when it is weathered away, there is outstanding a siliceous meshwork, as if it were penetrated by many minute veins that resist the action of the weather more successfully. It is perhaps this network of siliceous matter that suggested the idea of a fossil sponge. But, so far as the writer has been able to make out, this reticulated network exhibits no other sign of organic origin, and that alone is not sufficiently diagnostic of an organic origin.

As to the origin and date of these calcareous lenses seen so abundantly in some parts of the slates at Carlton, there is some uncertainty. Whether they are remnants of originally much more extensive calcareous masses, or are the result of growth by concretionary forces since the deposition of the clastic strata, is an interesting inquiry. It is probable that they do not retain the forms they once had, and that is the more evident if they be proven to be of clastic origin coeval with the rock enclosing them; for it is difficult or impossible to conceive by what manner of sedimentation such isolated, yet generally oval or rounded, bodies of limestone could be deposited in the midst of cotemporary sediments of grit or graywacke or of argillaceous slate. They manifest but little or nothing that can be called a concentric or concretionary structure, such as limy septaria are apt to exhibit. They are nearly, but not quite, independent of the sedimentation. They are sometimes somewhat governed in their distribution by the kind and direction of the sedimentary banding, and in some instances, even at Carlton, they coalesce and form thin strata conformable in the sedimentary beds. This dependence on the direction of the sedimentary bedding may be due to the action of original deposition, or to the accidental formation of beds in which these growths could later develop in a continuous sheet. These features show that sedimentation played an important part in the grouping of the calcareous matter if not in their origin, whether cotemporary or subsequent to the accumulation of the fragmental matter, and that, if cotemporary, they have changed their shapes. There are othei features that indicate that the calcareous matter, at least in the isolated globular bodies, is of later date than the siliceous grains that make up the mass of the surrounding rock, viz.: (1) The limy substance is crystalline, sometimes in so coarse a grain as to constitute thin sheets of calcite, though usually only as a granular crystalline mass. (2) In the latter case the crystalline calcite is quite frequently interspersed with clastic grains of quartz. These clastic grains of quartz are sufficient to preclude, apparently, an organic origin for the masses, but not sufficiently numerous to allow of the supposition that they

ever constituted the bulk and framework of the stratum. It is hence necessary to suppose that for some cause a copious deposit of lime has taken place so as to occupy the full dimension of the mass. In the region of Gunflint lake, pieces of flint of large size are embraced in a crystalline calcareous stratum.

For the present, therefore, the origin and nature of these problematic limy masses, as well as of the pure limestone strata of the Animikie at Gunflint lake, will have to remain unsettled. Mr. Jules Marcon has suggested to the writer their resemblance to the limestone "lentilles" of the Taconic slates of Vermont, and it appears a very reasonable suggestion. It has not yet, however, been possible to affirm that these masses are fossiliferous. It may be that under other circumstances and in other places they would be found to increase so as to constitute important limestone masses, comparable to those seen on the north side of Gunflint lake, and to the lenticular masses of Vermont.

The effect of dynamic action on the Thomson slates. The Thomson slates are in no sense a crystalline rock. They are very plainly of clastic origin, retaining sedimentary banding and bedding of the most pronounced characters, including ripple marks. They have been folded, faulted and compressed, and at a later date they have been invaded by numerous basic dikes whose width varies from a few inches to over one hundred feet.* These dikes have not been traced into actual connection with the great gabbro mass that occurs in the near vicinity, and there is reason to believe that they cannot be united to that rock in date and source, the principal of which is that dikes running parallel to these also cut the gabbro, introduced after the cooling of the gabbro. That these dikes were introduced at a date considerably later than the folding and faulting and the production of the slaty cleavage is evident from several considerations, viz.: The dikes show a freshness and freedom from dynamic action incompatible with the idea of their having suffered folding and faulting, *i. e.*, they are straight regardless of the folding of the slates, they are without schistosity, microscopically they do not show the effects of pressure and internal compression, and their direction is uniformly nearly north and south, transverse to the direction of the folding and faulting of the slates.

While it is impossible, perhaps, to demonstrate the exact date of the dynamic pressure which folded these slates, it is reasonable to attribute it, in part at least, to the event of the gabbro disturbance. If the slates be of the Animikie age, as supposed, and the dikes (which are supposed to be in part of the date of the Manitou) be excluded from that agency, there is no other known agent which can be invoked to explain and to cause this dynamic effect but the epoch of the Cabotian, *i. e.*, the

* The widest dike measured is that which crosses the St. Louis but a short distance below Knife falls. It is also seen west of the river where the Duluth and Winnipeg railroad crosses it. By pacing at this place its width was found to be from 280 to 300 feet, having a general north and south course.

gabbro intrusion. The general trend of the gabbro mass from this place to Pigeon point, is about parallel with the direction of the axes of the folding of these slates, and nearly perpendicular to the direction of the dikes.

There was also some interval of time between the tilting of these slates and the production of the slaty cleavage. It is true that very frequently the direction of the cleavage is parallel with the bedding, *i. e.*, about east and west, although the plane of the cleavage is nearly vertical, while that of the bedding is but rarely so. Were there no exceptions to this it might be inferred that these effects were the simultaneous results of the same cause, but there are occasionally considerable areas where the cleavage, running in the same direction, crosses the strike of the tilted sedimentary structure at a considerable angle. It is evident from this that the force that caused the tilting was a variable one as to direction, and operated at a date earlier than that which caused the slaty cleavage. The slaty cleavage keeps its east and west course whatever the direction or amount of dip.

Special structures in the slates. The effect of pressure on the slates is well seen in many places, but at Cloquet a peculiar structure is developed, not noted elsewhere, which seems to throw light on a structure often seen in the gneiss of the Archean.

The form of outcrop of the slates at Cloquet is a series of ridges which run sometimes ten or even twenty rods, but more frequently less than ten, in a direction nearly east and west, with roof-like slopes on the north and south sides, as illustrated by the cut below. The slopes are at an angle that would average about 45°, so that the ridges are generally sharper than a right angle. Toward the south the slope is coincident with and caused by the sedimentary structure, which is conspicuous in nearly all places, and but little disturbed by cleavage or by faulting. In the other

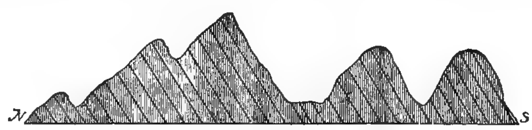


FIG. 106.

slope (north) the plane of the roof is caused by a series of joints, along which there seems to have been an easy faulting, the direction of which plane is not, however, coincident with that of the multiple faults to be described later. The sedimentary structure, which can be seen running on the northern sides of these ridges, is very evident in the varying grain and in all the color-banding which indicates the sedimentary origin. Sometimes, for several rods, a line of holes, made by the weathering out of small calcareous lumps, such as have already been described in this rock, can be seen on the north side, making a calcareous stratum which has had its lime gathered into isolated patches. Such little holes are sometimes (especially when they continue far in this manner) mere gashes about two or three inches long and opening

FIG. 1. VIEW OF CRUSHED SEDIMENTARY ROCK, LOOKING ON A JOINT PLANE WHICH CUTS THE ROCK NEARLY PARALLEL TO THE BEDDING. (p. 559.)

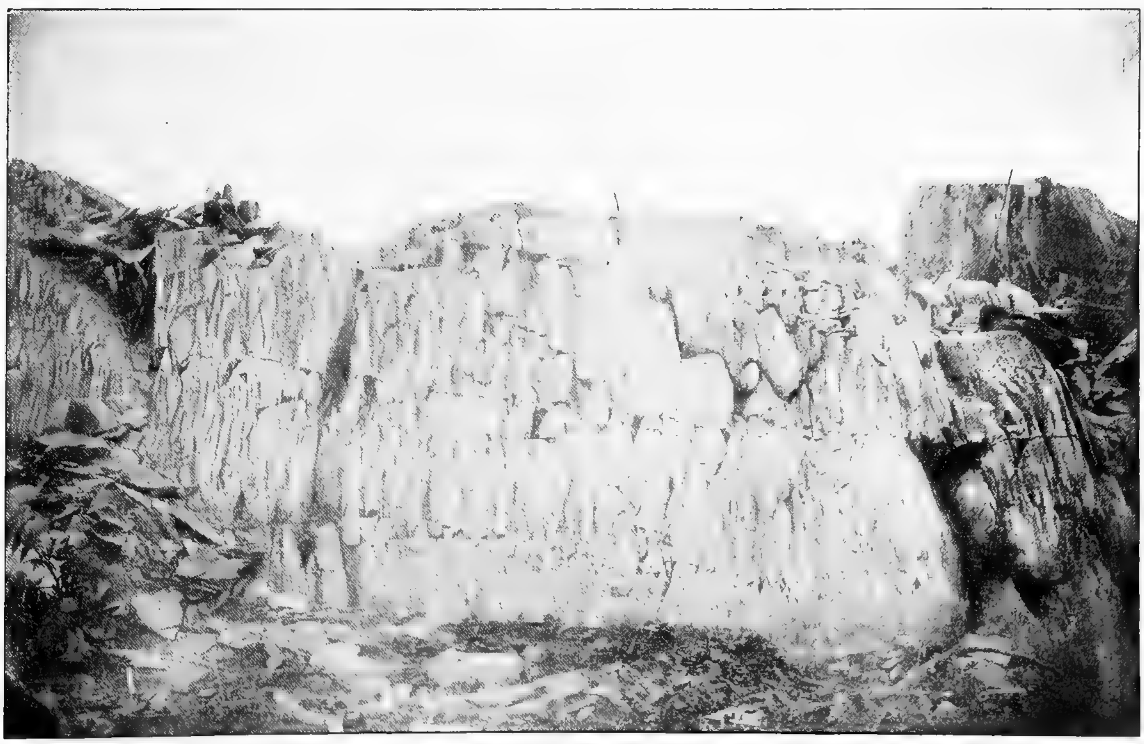


FIG. 2. EFFECT OF SHEARING PRESSURE ON THE THOMSON SLATES, CLOQUET; VIEW OF JOINT SURFACE CUTTING THE ROCK NEARLY PERPENDICULAR TO THE BEDDING. (p. 559.)

about a quarter or a half inch, standing vertically in the original stratum; and sometimes they are larger openings, more nearly globular, which rudely maintain a parallelism with the sedimentary banding. Other features of this sedimentary structure might be mentioned, viz., the gray slates vary to a fine graywacke, yet of so coarse a grain that the rock is not slate; indeed, in the coarser beds the slaty cleavage is imperfect or wanting, or the cleavage planes are farther apart. This difference in the grain is probably the prime cause (on the application of pressure) of the peculiar structure which is here to be described.

The slaty cleavage is about vertical, running about east and west; as the ridges themselves vary a little to the northeast, the cleavage direction crosses the ridges at a sharp angle, and hence also crosses the sedimentary structure at a similar angle. There are also various jointage systems in which cannot be seen any general uniformity of direction, although one which seems to prevail more widely than the rest runs south-southeast, crossing the cleavages about as the cleavage cuts the sedimentary structure, but it slopes toward the north-northeast at an angle of less than 45° from the horizon. Another jointage system is about horizontal and facilitates the removal of the tops of the ridges, producing tabular surfaces. This, however, is not common. Another system is about parallel with the sedimentary structure and causes the southerly roof-slopes. Other joints run in other directions, and in one instance was seen a series of joints radiating from a centre, which centre was in the open plane of a larger jointage system. The joints are apparently all of later date than the cleavage and cut it in all directions without producing any apparent effect upon it. They likewise have had no agency in producing the problematic structure illustrated below. It is also quite evident that this structure, and the cleavage, which are inseparable, were produced in the rock later than the tilting which brought the beds to their present position.

That which first attracted attention was a structure seen on the southerly slopes of several of these ridges, of which subsequently a photograph was made, which is reproduced in plate YY, figures 1 and 2. This resembles a sedimentary structure so greatly, in some of its phases, that it gave at first the impression that there was locally a change in the direction of dip from that which everywhere prevails. What is more strange still was the existence, on the north sides of the same ridges, though not in perfection, of the evident true sedimentary banding running in the usual direction, showing that there was actually no bodily disturbance of the rock as a whole other than that which could be seen in the other ridges. Figure 1, seen in plate YY was taken from the south, and shows the southern slopes of these ridges. Figure 2 of the same plate was taken from the north. It was only after long and minute inspection of these ridges, which really show variations in the degree of development of this pseudo-stratification, that its cause was discovered.

A series of drawings (plate ZZ) made on the spot from nature will illustrate the aspect of the southerly slopes of several of these ridges, beginning with the least and ending with the most peculiar.*

Figure 1 shows a normally cleaved southern side of one of the slaty ridges, the cleavage being nearly vertical but crossing the ridge at a sharp angle so as to appear on the southerly slope.

Figure 2, showing on the southern slope spots of non-cleaved rock, somewhat irregularly disposed amongst the fine-cleaved slate. On inspection these non-cleaved spots are seen to be of the same grain as the graywacke, and coarser than the slates proper. They are rudely elliptical, elongated in the same direction and conformable in general with the direction of the slaty cleavage.

Figure 3, showing the southern slope of one of these ridges wholly taken up with these non-cleaved areas in lenticular forms, separated only by small quantities of the finer-cleaved or crushed rock, which are arranged in conformable films surrounding the non-cleaved areas.

Figure 4, showing on the southern slope a somewhat regular arrangement of the non-cleared spots. [These are here represented rather too systematic and too far separated.]

Figure 5, showing a loss, or nearly so, of the horizontal component of arrangement, and an augmentation of the vertical, producing a vertical banding more or less perfect, the fine material being abundant.

Figure 6, showing entire loss of the horizontal component and an increased distinctness of the vertical, and at the same time a diminution of the finer material, making a persistent vertical banding that simulates sedimentation.

There are various intermediate stages, but the above are the principal phases. They are all visible and can be connected by actual observation of the intervening steps. There are also many little irregularities.

As has been stated, these features are closely connected with the slaty cleavage, and indeed are apparently only a special development of it. It has been stated that slaty cleavage is the result of a repeated succession of minute faults which pervade the whole mass of the rock affected. Such a principle is demonstrable here by observation. It is also demonstrable that this faulting is not so easily effected in the coarser layers of the fragmental rock, but that when the coarse rock is faulted it is at larger intervals, producing blocks rather than slates.

On the northward slopes of these ridges where this pseudo-stratification is produced, are various interruptions and irregularities in the color bands marking the sedimentation. Sometimes the banding is curled and sometimes it is faulted extensively, although the former continuity is still exhibited by the aggregate continuance of the banding across the whole face. One such irregularity was sketched from nature, as shown by figure 7, plate ZZ.

Here can be seen a squeezed-out segment of a coarser-grained layer (b) into a finer-grained layer (a). The layers (a, a, a) are of fine material and slaty; b and b are coarser and evidently more siliceous. It is a representation of actual fact, seen in one place.

The fact illustrated by figure 7 is the key to the whole structure. A portion of one of the coarse beds (b) is removed from its position and thrust bodily amongst the fine-grained layers (a), but it nowhere has the slaty structure of (a). It is plain that to get the space formerly occupied by it closed, the parts of the layer (b), from which the mass (c) was removed, must have been brought bodily toward each other. This motion indicates a compression in the direction of the strike, or somewhat obliquely

*Fortunately these ridges have been burned over in the process of clearing off the forest, and changed by the weather so that the varying grain is evident and can be traced in its thread-like foldings by the fine reticulations which it produced on the surface.

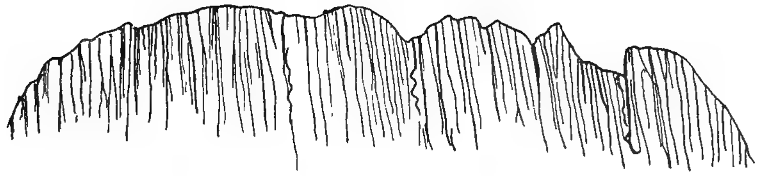


Fig. 1.

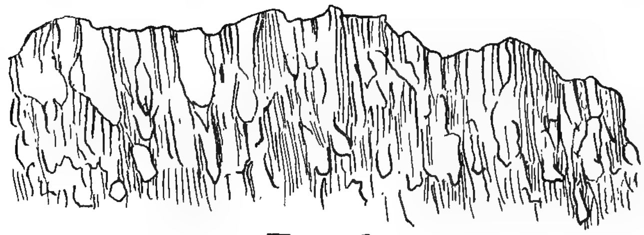


Fig. 2.

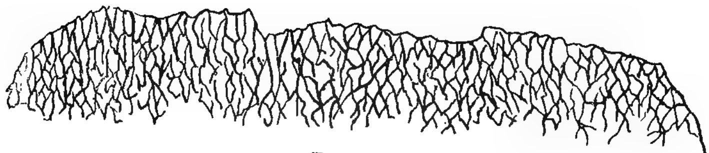


Fig. 3.

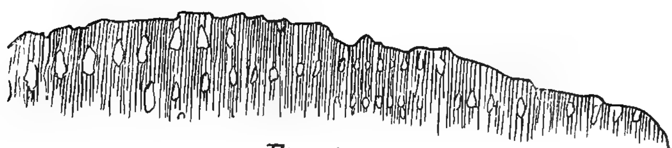


Fig. 4

Fig. 5.

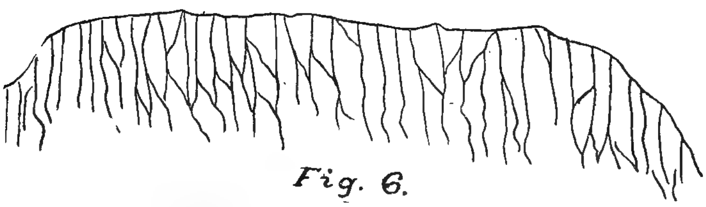


Fig. 6.

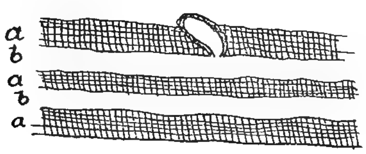


Fig. 7.

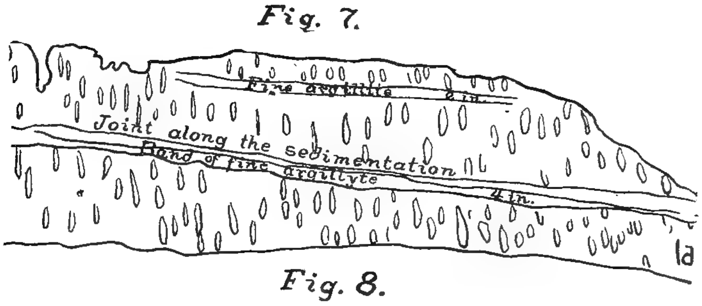


Fig. 8.

EFFECTS OF SHEARING AND PRESSURE ON THE THOMSON SLATES.

to it, of the entire rock mass, and would compress necessarily the layers (a, a, a). The difference in the grain of these layers was probably the chief cause of the difference in the manner in which the layers accommodated themselves to this pressure, *i. e.*, the fine layers fractured minutely and numerously, producing a slaty cleavage, and the coarse layers fractured loosely into large blocks, producing a coarse schistosity. It is only necessary to multiply this coarse faulting to produce the structures seen in the foregoing figures. Then, later, when, by jointing and weathering, this structure is cut and exposed to the atmosphere, an apparent gneissic structure is brought to view, similar to that which is seen in some Archean gneisses, which sometimes has been reported as sedimentary. It is evident that in such a structure, produced by this process, whether in the clastic or the crystalline strata, there has been an entire crushing and rearrangement of the elements of the bedding of the rock. The structures evident in figures 2, 4 and 5, above, and that in figure 1, of the half-tone plate YY, are exposed by a jointage that cuts the rock nearly parallel with the original sedimentary bedding, the protruded portions of the coarse layer, as they lie somewhat systematically in the adjoining finer layer, being favorably sectioned by a joint plane. Structures such as those seen in figures 3 and 6, and figure 2 of the half-tone plate, may be exposed by a plane cutting the bedding planes perpendicularly or obliquely, and they prove that the coarser strata of the formation are entirely brecciated by a lateral thrust, the analogue of the minute cleavage-fractures of the fine, slaty strata. Indeed, the photograph reproduced in figure 2 of plate YY is a view looking nearly south against the strike of the sedimentary structure, and two layers of fine argillitic rock extend across its face from right to left. It is roughly redrawn in figure 8 (plate ZZ) for further description.

Bands of argillitic grain and composition, not well brought out in the photograph, two in number, are represented in this drawing, the upper one being two inches and the lower four inches in width. Nearly parallel with the latter a joint plane cuts the rock through this argillyte. If the joint could be opened it would probably exhibit a structure like that seen in figure 4 or in figure 5, showing portions of the coarser rock thrust amongst the finer. It is also plain from this figure, and especially from the photograph which it represents, that the whole rock is in a crushed condition, and that the jointage planes cutting it in any direction would reveal the same structure in the coarser beds. The material that surrounds the uncrushed pieces of the coarser layers is the debris that resulted from the crushing, arranged in a coarsely schistose manner about the uncrushed pieces.

It may be remarked, as a corollary, that after a sedimentary rock shall have been thus crushed, if it should be subjected to regional metamorphism it would show a structure similar to that seen in some gneisses, but that the direction of the gneissic structure would not be that of the original sedimentary bedding.

As a second corollary it may be noted that, had this rock ever contained fossils, they would be badly broken, if not obliterated, by this crushing.

This coarse brecciation is seen only in the coarser strata. It is evident, however, that equal compression and disturbance must have affected the finer strata. This is apparent, but it is in the form of minute faults, producing or at least accompanying the slaty cleavage. Figure 1, of plate XX, represents a folded condition of this formation as exposed by the railroad cut about two miles southeast from Carlton. Here various interesting features are to be seen. The photo shows, in the main, one anticlinal fold, but there are also some synclinals, less exposed. The same structures seen at Cloquet, above illustrated, are but faintly exhibited here. There are limy concretions or balls scattered rather promiscuously about, but at the east end of the cut they prevail exclusively in one of the siliceous sedimentary beds, being in lumps on the upper side. Besides the conspicuous general folding of the sedimentary layers, the next most noticeable feature is a coarse lenticular-slaty cleavage which pervades all the rock except some narrow siliceous (flinty), nearly black layers, which seem to have been proof against the production of this structure. This gives the rock a fiber rather than a cleavage. It runs about east and west, as at Cloquet, but it never appears as a good slatiness.

There is another fine lining, which also occurs at Cloquet, and at some of the slate quarries southward from Cloquet. This fine lining has been seen to spread over the whole surface of some of the slates taken out for roofing, and on some of the weathered, yet smooth, knobs, it might be mistaken for a fine sedimentation, but it transgresses the actual sedimentation at all angles. It is usually somewhat curving and even tortuous, and becomes most visible on the opening of the cleavage partings. Sometimes one set of these markings abut non-conformably against another, ceasing entirely. The line or plane of juncture of the two systems is characterized by a little sharp elevation, giving the suggestion that perhaps one set runs below the other, nearly parallel with the cleavage planes. On close inspection, however, this lining is seen to be due to a system of fine ridges and depressions, the direction of which, continued through the rock as a succession of waves, lies at an angle of nearly 90°, or nearly perpendicular to the principal slaty cleavage. It is not a feature, therefore, dependent on the cleavage. A fresh piece of the rock, taken from the railroad cut (No. 1979), exhibits this fine striation, both on the planes of the slaty cleavage and on their edges. It is coarser in the coarser slates, and in the very fine (nearly black) strata of the slates it is perceptible sometimes only by the use of a magnifier. In all cases it is plain to see that it is an internal undulatory structure, which, on being exposed by the cleavage of the slates, appears as alternating ridges and depressions. These are brought out more distinctly by putting the

specimen in position favorable for different angles of reflection of the light. It is another evidence of the compression and molecular disturbance to which these strata have been subjected.

It was observed, in several cases, on the surface of a roofing slate from Dietz and Dougan's quarry, about three miles south of Cloquet, that this striation radiated from central spots not thus marked or differently marked. This is represented by the figure below (figure 107), sketched from nature. The central spot was nearly two inches across. A ring (a) of much lighter color forms the outside of the spot. It is without the striations, and all the radiating striæ cease at its outer bound. Within this ring are no visible radiations, but instead an indistinct circular banding (c, c) of somewhat lighter and darker bands, but in the main, within the larger, outer ring, the material was fine and black and almost homogeneous as to kind and color. A little at the left of the centre appeared a small elevation (d) in the slaty substance, as if the nucleus of the concretion (?) had been the locus of a knotty and hardened growth. This was black and about the size of a small pin-head. From the large band of color (a) the striated structure spreads so as to embrace and cover the whole cleavage surface of the slate uniformly in all directions. This is also found on all of the slates, though it is always much varied in direction, making sometimes rather handsome frond-like forms. It appears from this that compression alone is not sufficient for the production of these striæ. It is probable that, given sufficient pressure, the direction of the undulatory minute faultings would be determined by the varying obstructions that might pre-exist in the rock, such as varying sedimentation and irregularities in the composition of the rock. It is a structure, however, which requires further study before it can be said to be understood.

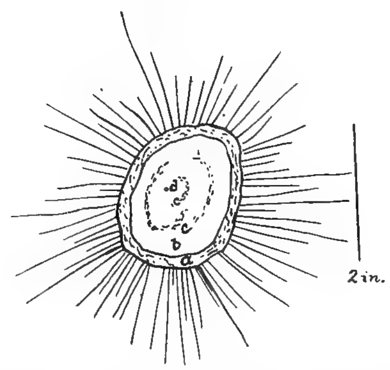


FIG. 107. RADIATED STRIATIONS ON THE SURFACE OF A SHEET OF ROOFING SLATE.

Again, on the edges of the lenticular slaty slabs produced by the crushing of some of the coarser strata of the formation in a manner similar to that already described at Cloquet, but seen, in this instance, at the railroad cuts southeastward from Carlton, is a series of coarser undulations (Nos. 1978, 1979). These are likewise nearly perpendicular to the slaty cleavage, but the distance between the crests of

two of the undulations is in some instances an inch, or even three inches, a space sufficient to embrace from twenty-five to forty of the undulations already described. These troughs, which have a sort of synclinal and anticlinal alternation, have a *pitch* toward the east about parallel with that of the grand folding shown in the plate (figure 1). It seems from this, also, that a series of zigzag minute crushings and faultings, intermediate in size between the fine striations and the coarse brecciation of the graywackes, took place throughout the mass of some of the strata. It is probable that these structures, from the coarsest to the finest, are due to the same cause. They are not coincident with the cleavage but cross it, usually at a large angle. They probably indicate different directions of intense pressure and a varying degree of force.

At the second railroad cut (toward the west), the walls rise about thirty feet in extreme, and the dip is about 75° to 85° N. This cut is near the east end of an extended rock ridge.

At the third cut, about one-fourth mile further west, the rock dips south at 45°. Here a dike forty-six feet wide runs N. 30° E., probably one of those that pass through the rock at the village of Thomson.

At the next cut, and also at the last, the rock dips toward the south. The rock at the former consists of a greenish dense graywacke, of massive aspect, rising in a prominent east-and-west ridge, having at the top a coarse jointage that causes the ridge at a distance to resemble gabbro. A dike six feet in width cuts it in the usual direction.

According to Mr. H. B. Ayres, the most easterly points at which this formation is visible about Carlton are the following: Sec. 6, T. 49–15; east line of sec. 18, T. 49–15; sec. 29, T. 49–15; and the nearest point at which gabbro is known to approach this formation is N. W. corner sec. 33, T. 49–15, the surface distance between them being less than a mile.

Conglomeratic aspects of the Thomson slates. The question of the age of the Thomson slates has already been considered. If they are of the age of the Animikie, they must lie non-conformably on some older formation, which is presumed to be the Keewatin. There are some evidences of this in the pebbles that occur in the Thomson slates in the vicinity of Otter Creek station. These pebbles are black, and purplish, cherty and quite hard, and some are of an older graywacke. Some of the rounded, coarser slate pieces, or graywacke, are five by eight inches. Some of the irregular, hard, black, cherty masses are two feet long, and others seem to have come from an earlier conglomerate.

These facts are in perfect accord with the Animikie age of this rock, but can hardly be explained on the hypothesis that the rock is earlier than the Animikie.

The only other older conglomerate known is that at the base of the Upper Keewatin, but it has never been known to contain pieces of still older conglomerate. It is made up of crystalline debris.

A curious boulder. At Cloquet may be seen a curious, sharp knob of red-and-white amygdaloid, situated between the "Nelson House" and the river, nearer the river, and somewhat to the east of a line running north from that hotel. At first glance this rock appears to be *in situ*, as it has a structure and a dip parallel with the dip of the slates and graywackes. It is about twelve feet long, and was ten feet high above the rest of the rock of the place, but it has been broken by some quarrying. It is an attractive and handsome object. It is spotted with red, white and green, mainly in amygdaloidal forms—probably calcite, orthoclase and epidote—but the red sometimes constitutes a granular rock, and its spots are from the size of peas to areas two to four inches long, of irregular width, but usually not more than half an inch thick. These may have been inclusions in the basic trap from contact with some sedimentary. In case of becoming an amygdaloid such a trap would be likely to have its gas-cavities variously affected by and associated with such inclusions. All in all, though this is probably a Cabotian boulder, it is a remarkable exhibition.

ROCK SAMPLES.

The following rock samples were collected within the area of this plate:

By N. H. Winchell: 449–510; 1607–1614; 1974–1979.
By U. S. Grant: 1017G–1019G.
By A. H. Elftman: 264E–265E.

CHAPTER XXXI.

THE GEOLOGY OF THE DULUTH PLATE.

(PLATE 88.)

BY N. H. WINCHELL.

The most important, as well as the most conspicuous, element in the geology of the vicinity of Duluth, is the gabbro which forms the hill-range that outlines the basin of lake Superior at that point.* This range of hills forms an elevation which is very noticeable from the east as the traveler approaches the west end of the lake, and it can be seen to extend far beyond the present limits of the lake. To this hill range, essentially that formed by the gabbro, Mr. Schoolcraft applied the name "Cabotian mountains," a title which, according to his statement, was first given by Bouchette, "being a continuation of the upheavals of the north shore of lake Superior."

Within the limits of the Duluth plate the lakeward side of this hill range descends abruptly to the level of lake Superior about 600 feet, the whole change being effected generally within the interval of less than a mile. Eastward from Duluth, however, the change from the high land to the lake level is much more gradual as the gabbro strikes away from the lake shore. The most western point at which this rock has been observed in place is at the northeast corner of sec. 32, T. 49–15, which is about a mile north of Short Line Park station on the St. Paul and Duluth railroad. Here

*Published descriptions of some portions of this area may be found as follows:

J. H. KLOOS. Geological notes in Minnesota: *Zeitschrift d. deutschen Geologischen Gesellschaft*, p. 417, 1871. Translated and republished in the *Tenth Annual Report* of the Minnesota geological survey.

A. STRENG and J. H. KLOOS. The crystalline rocks of Minnesota: *Neues Jahrbuch für Mineralogie* (1877). Translated and republished in the *Eleventh Annual Report* of the Minnesota survey (for 1882).

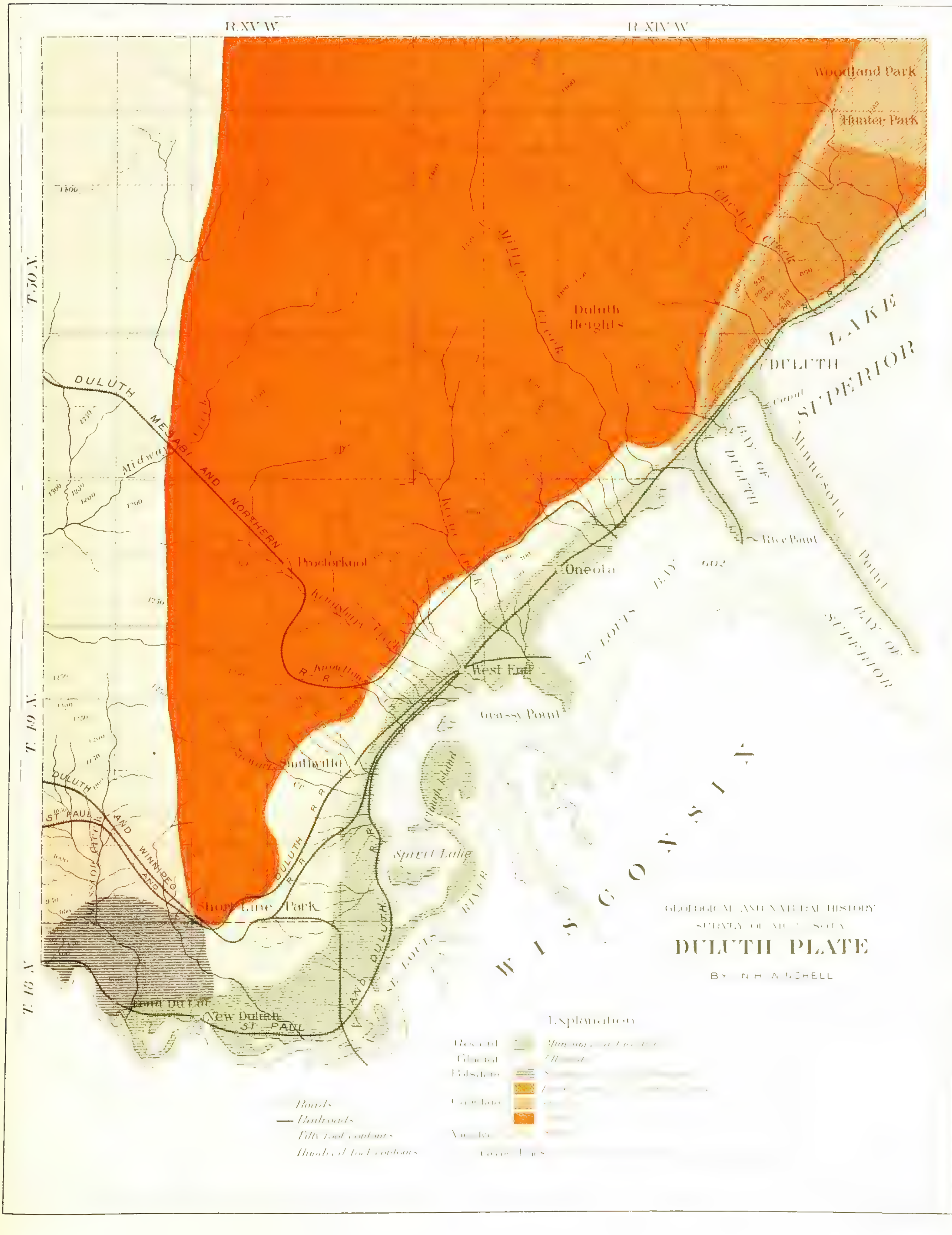
Geognostic and geographic observations in the state of Minnesota: *Zeitschrift der Gesellschaft für Erdkunde zu Berlin*, Bd. xii, 1877. Translated in the *Nineteenth Annual Report of the Minnesota Survey* (for 1890).

N. H. WINCHELL. The Cupriferous series at Duluth: *Eighth Report of the Minnesota Survey*, pp. 22–26. Preliminary list of rocks: *Ninth Report of the Minnesota Survey* (for 1880). The cupriferous series in Minnesota: *Proc. Am. Assc. Adv. Sci.*, 1880. Preliminary list of rocks continued: *Tenth Annual Report of the Minnesota Survey* (for 1881), pp. 34, 35, 107–109, 137–148. Typical thin sections of the rocks of the Cupriferous series in Minnesota: *Proc. Am. Assc. Adv. Sci.*, 1881. The crystalline rocks of the northwest: *Proc. Am. Assc. Adv. Sci.*, 1884. Reprinted in the *Thirteenth Annual Report of the Minnesota Geological Survey*. The lake Superior rocks: *Science*, vol. i, p. 334. Some thoughts on eruptive rocks with special reference to those of Minnesota: *Am. Assc. Adv. Sci.*, 1889. The Duluth deep well: *Bul. No. 5, Minn. Geol. Sur.*, 1889, p. 31. The Norian of the northwest: *Bul. No. 8, Minn. Geol. Sur.*, 1893 (prefatory note). Crucial points in the geology of the lake Superior region: *Am. Geol.* Several papers in 1895.

R. D. IRVING. On the age of the copper-bearing rocks, of lake Superior, and on the westward continuation of the lake Superior synclinal: *Am. Jour. Sci.*, 1874 (3), viii, 46–56. Geological structure of northern Wisconsin: *Geol. Wis.*, vol. 3, p. 3. The Keweenawan or copper-bearing system. *Geol. Sur. Wis.*, vol. iii, pp, 167–206. Lithology of Wisconsin: *Wis. Geol. Report.* vol. i, 1883, p. 340. Copper-bearing rocks of the lake Superior region: *Third Annual Report of the U. S. Geol. Sur.*, pp. 93–188, 1883 (See also *Sci.*, vol. i, pp. 140, 359 and 422); ditto, *Mon. v., U. S. Geol. Sur.*, 1884.

S. T. SWEET. Geology of the western lake Superior district: *Geol. of Wis.*, vol. iii, pp. 305–362, 1880.

J. G NORWOOD. See Norwood's report in the report of D. D. Owen, on the *Geology of Wisconsin, Iowa and Minnesota*, made during the years 1847, '48, '49 and '50, pp. 341–345. Quarto, Philadelphia, 1852.



R. XV W.
R. XIV W.
T. 50 N.
T. 49 N.
T. 48 N.
Woodland Park
Hunter Park
Chester Creek
Miller Creek
Duluth Heights
DULUTH
LAKE
SUPERIOR
Canal
BAY OF DULUTH
Minnesota Point
Rice Point
BAY OF SUPERIOR
ST. LOUIS BAY
DULUTH MESABI AND NORTHERN
Midway
Proctorknot
Oneota
West End
Grassy Point
Spirit Lake
ST. LOUIS RIVER
Short Line Park
Fond Du Lac
New Duluth
DULUTH ST. PAUL AND WINNIPEG
ST. PAUL
WISCONSIN
GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA
DULUTH PLATE
BY N. H. WINCHELL
Explanation
Glacial
Roads
Railroads
Fifty foot contours
Hundred foot contours

it comes within about a mile of the most easterly known exposure of the Thomson slates, which are to be seen at several places along Mission creek in section 31. (Compare rocks Nos. 446 and 447.) Slates also appear in section 29, as reported by Mr. Ayres.

Back from the face of the gabbro escarpment, which is in some places nearly perpendicular, the elevation still rises slightly, forming an undulating drift-covered plateau, which, along the north side of the plate, reaches the altitude of over 1,400 feet.

The nature and age of the slates are discussed in the chapter devoted to the Carlton plate (plate 87), and nothing further needs to be said on that subject except to remark that the gabbro, being younger than the slates, seems to have overwhelmed them and involved them in itself, in small and large masses, sometimes fusing them and sometimes simply hardening and metamorphosing them. These features, however, will be considered in the description of the gabbro itself.

The Fond du Lac sandstone, however, requires further description. It is partly discussed in connection with the Carlton county plate (plate 56). This rock (Nos. 443–449) dips toward the south and southeast, and is exposed on both banks of the St. Louis river from Fond du Lac westward to the point at which it is replaced by the quartzose pebbly conglomerate that lies non-conformably on the Thomson slates. The following record bears on the nature of this sandstone:

*The Short Line Park deep well.** This well commences at an elevation of about 900 feet above the sea, and therefore about 300 feet above lake Superior. The drillings which were sent to the survey in 1888 by Prof. W. F. Phelps, secretary of the Duluth Chamber of Commerce, were well washed and carefully preserved in bottles marked to show the depths from which they severally came. They afford a valuable guide to the structure of the rocks underlying the region, and owing to the importance of the stratigraphic succession which they reveal, they have been examined again recently with a view to the verification or correction of the record at first published. It was found that the original description needed but little change. In the following description these changes are inserted and more detail is given in respect to some of the strata:

Record of the deep well at Short Line Park.

	Thickness in feet.	Depth of well in feet.
1. Earth,	100	100
2. Rock (?), no drillings preserved,	131	231
3. Brownish-red, finely granular, homogeneous, with little free silica. The material is eruptive, perhaps a tuff,	12	243
4. Is an epidotic, probably amygdaloidal trap, brown. This character is apparent on rewashing some of the drillings. It is decayed, and may be assumed to have been a surface flow,	33	276
5. No drillings (probably eruptive),	104	380
6. Same as No. 4, but more plainly a surface eruptive,	37	417

* This well has been described in *Bulletin v* under the name "Duluth deep well."

		Thickness in feet.	Depth of well in feet.
7.	Nearly the same as No. 4, grayish brown; some of this material appears fragmental,	31	448
8.	A fine-grained siliceous slate, gray, probably from the slate formation below the depth of 619 feet (No. 28). Fifteen feet.	...	...
9.	Essentially quartzose; the grains vary from limpid quartz to gray, or pink and purplish; some of the larger are composed of grit, the constituent grains being rounded. After rewashing a quantity of the drillings, there is no certainty of any feldspar in this lot, but there are a few pieces of rock like No. 4,	5	453
10.	Similar to the last but coarser. There is in this a fragment of amygdaloidal trap somewhat over a quarter of an inch across, one side of which shows it was a rounded pebble, and the fractured side of which shows green-coated amygdaloid indistinguishable from the amygdaloids so common at Duluth. There is but little of this preexisting old trap material in the drillings. Slightly pyritiferous,	5	458
11.	Siliceous slate, identical with No. 8; belongs below No. 28. Seventeen feet,	...	...
12.	Drillings brown, with green grains of epidote (?), white grains of calcite and of quartz, and red grains of orthoclastic material. The needle does not pick out grains that are plainly of magnetite, but scales of rusted metallic iron, derived from the drill. This iron is found also in all the foregoing. The rock is not typical gabbro, but represents one of its modifications. It is rather fine-grained,	16	474
13.	Is probably a conglomerate, but containing much soft eruptive matter. No characteristic felsyte is visible, but some brownish-red pieces that may still have come from basic flows. While probably Cabotian originally there is nothing here certainly characteristic,	2	476
14.	Evidently a conglomerate that contains principally brown felsyte; also brown shale, and white and gray quartz and granular quartzyte. The shale is perhaps the matrix, and has mainly disappeared in the process of drilling and washing the drillings. It is slightly pyritiferous and epidotic. The materials are Animikie and Cabotian, with a Keweenawan cement,	3	479
15.	Pink and gray, quartzose pyritiferous conglomerate and granular quartzyte, although in the main a firm granular and quartzose rock, seems also to have contained pebbles of Animikie slate,	2	481
16.	Drillings are principally granular white or limpid quartz, in small angular grains. The cement seems to have been of the same material in finer grains,	1	482
17.	Same as the last, evidently a white granular quartzyte,	2	484
18.	Same as the last, but much coarser; might be a conglomerate,	4	488
19.	Same as No. 18,	4	492
20.	The same,	4	496
21.	Dark gray, pulverulent; when washed these drillings seem to contain also fine eruptive basic rock and vein quartz,	2	498
22.	Trap-rock, epidotic diabase, some fragments brown; drillings fine and generally of a gray color,	24	522
23.	Same as the last, with some brown grains; probably amygdaloidal; epidotic,	20	542
24.	Rather fine trap-rock, with some brown, similar to the rocks at Duluth,	16	558
25.	Same as No. 24 (when rewashed), but finer,	8	566
26.	Brown-gray diabasic rock, rather coarse-grained,	15	581
27.	The drillings are of two sorts, (*a*) brown, granito-felsitic, and (*b*) gray, fine-grained and trap-like; some of the latter appearing to be porous or amygdaloidal or fragmental,	6	587
28.	Black slate or argillyte, aphanitic and purplish, occasionally embracing fragments of coarser grit-rock, as well as of light-green, softer slate or schist. This black slate has a slaty cleavage, but it cannot be determined whether it is coincident with the sedimentary bedding, although it appears to be independent of such a structure; evidently the Thomson slate formation,	61	648
	About here belongs No. 8,	15	663
	About here belongs No. 11,	17	690

		Thickness in feet.	Depth of well in feet.
29.	The same as the last; with some drillings of white vein-quartz,	200	890
30.	The same, but having a greenish tinge apparent, and being some softer,	200	1090
31.	No drillings,	90	1180
32.	The same as No. 28,	5	1185
33.	The same as No. 30, -	60	1245
34.	Essentially the same rock, but apparently not so slaty, with vein quartz,	105	1350
35.	The same, rather light gray,	30	1380
36.	Gray slate, slightly pyritiferous; evidently slaty cleavage,	5	1385
37.	The same as the last,	25	1410
38.	Drillings are of two kinds, (1) dark gray slate (?) like the last, and (2) a lighter rock, apparently hydro-micaceous slate,	35	1445
39.	Drillings very fine and of a light yellowish color. Thorough washing leaves a residue of fine quartz grains mainly; but this does not indicate the general character of the rock, as the matrix of these grains is evidently lost by the washing. These grains are mainly white, sometimes glassy, but of various shapes and sizes. They cannot be said to be waterworn, and are themselves minutely granular when magnified about 40 diameters. Mingled sparsely with the white and glassy grains are also a few that are purplish, or gray, and also some of a loose, hydromicaceous schist. The general yellow-rusty color is caused probably by the oxidation of iron scales derived from the drill. These scales pervade all these drillings,	2	1447
40.	The same as the last,	8	1455
41.	The same as the last. In this can be seen, under the microscope, some fragments of a rock that appears to be a kaolinic itacolumyte and it is not unlikely that they are from the rock that furnishes these quartzose washings,	3	1458
42.	The same as the last, but also contains some drillings like the next,	2	1460
43.	Gray compact, very fine-grained, crypto crystalline or fragmental, diabasic (?) rock,	2	1462
44.	Same as the last, but also contains some gray slate,	2	1464
45.	Same as No. 43,	1	1465
46.	The same fine-grained gray rock predominates; under the microscope it appears to consist of fine glittering grains resembling quartz,	1	1466
47.	Same as the last, but more evidently a fragmental gray quartzyte,	1	1467
48.	The same, but somewhat lighter-colored,	10	1477
49.	Same as the last,	10	1487
50.	Gray quartzyte, very fine, same as No. 46, -	10	1497
51.	The same,	8	1505
52.	The same, but some grains are apparently from a somewhat cleavable rock, though not argillitic,	5	1510
53.	The same graywacke, evidently slaty and finer-grained,	7½	1517½

Summary of the Short Line Park deep well. Previous to reaching the depth of 231 feet no drillings were preserved. It is to be supposed that this interval was partly occupied by red sandstone and shale, viz.: 131 feet, same rock as seen in the banks of the river adjacent, perhaps with more or less eruptive materials. The first drillings preserved are of eruptive nature (No. 3), and this rock which, given a thickness of twelve feet, passes into an amygdaloidal trap, which is recorded as having a thickness of thirty-three feet, after which is another unknown interval of 104 feet, but which, considering that the same rock (amygdaloidal trap) recurs below it, may be supposed to have been occupied mainly by eruptive strata, but probably embracing also fragmental materials such as reddish conglomerates and sandstones, products of cotemporary eruptions. The foregoing, a mass of bedded eruptives, having a thickness of 217 feet (Nos. 3 to 7 inclusive), plainly belongs to the Manitou eruptive epoch, *i. e.*, the upper part of Irving's Lower Keweenawan. The sandstones overlying, included in the first 231 feet, are Irving's Upper Keweenawan.

Below these eruptives follows a series of hard quartzytes, and quartz conglomerates, with but little eruptive material, including Nos. 9 to 20 inclusive, having a thickness of forty-eight feet. The striking similarity of this to the pyritiferous white quartz conglomerate seen in the left bank of the St. Louis river a little west of Short Line Park, leaves no alternative but to parallelize it with that rock. But here, instead of lying on the Thomson slates, it lies on another series of eruptives which exhibit a thickness of ninety-one feet. These eruptives are amygdaloidal, and resemble greatly those that occur at Duluth and eastward to Chester creek. It seems necessary to parallelize them with the flow rocks at Duluth. These rocks, as represented by these drillings, are not wholly free from fragmental materials, neither are they along the lake shore at Duluth.

Below this second series of eruptives is found the Thomson slate, the supposed equivalent of the Animikie. This formation, although penetrated by the drill to the bottom of the well, 1,517½ feet below the natural surface, developing a thickness, as penetrated, of 930½ feet, was not pierced at that depth. These parts may be put together succinctly as follows:

		Feet.
1.	Drift and red sandstones of Fond du Lac, no drillings,	231
2.	Eruptives (surface flows, etc.),	217
3.	Pyritiferous quartzyte and quartz conglomerate, -	48
4.	Surface flows, as at Duluth,	91
5.	Slates, as at Thomson,	930½
	Total,	1,517½

There are several things to be noted in this record.

1. The Fond du Lac sandstones are chronologically separated from the quartzose, pebbly conglomerate on which they lie at the river, by a series of surface eruptives. This marks an important physical event as transpiring in the immediate neighborhood between the date of the quartzyte and conglomerate, and that of the Fond du Lac sandstones. This physical change in the environment is indicated by the change in the nature of the accumulating cotemporary sediments, viz., from siliceous sediments to sediments of eruptive fragments, although at the river there is no apparent stratigraphic break. Fine, basic eruptive debris, even constituting red conglomerates, is so abundant in the lower portion of the Fond du Lac sandstones as to constitute strata several feet thick, having alternating shale beds. This is illustrated by figure 2 of plate XX, which was taken as a photograph at the mouth of a creek entering the St. Louis river near the old station of Greely. The conglomerate beds are fifteen or twenty in number, separated by red shale and sandstone.

2. The gabbro, as such, is wanting, and in its place is a series of eruptive basic flows, which are identical with those seen at Duluth. This indicates that the gabbro intrusion, which immediately followed the Animikie, appeared as a succession of

extrusions at the surface. This is also in keeping with the succession at Duluth, but it makes the Duluth surface eruptives of the age of the gabbro, and earlier than the Manitou eruptive epoch.

3. The bottom of this lower series of eruptives (No. 27) is characterized by the same features as have been noted at many places where the gabbro forms a contact on the Animikie, viz., the fusion and blending of the fragmental rocks with the basic eruptive, producing two sorts of rock, both apparently eruptive, one acid and one basic, the former the result of such fusion. Similar transitions from the gabbro occur on the hills at Duluth much more strikingly. Such fused material may not all come from the Animikie, but may be derived from any earlier acid rock, either fragmental or crystalline.

The age of the Fond du Lac sandstone. This rock, being closely connected with the later eruptives, must be about cotemporary with some of the Manitou flows of the Keweenawan. The gradual dying out of the eruptive action rendered the sandstone more and more siliceous, and it appears that the upper strata are almost free from the shaly, red sediment that characterizes the lower portion. The rock thus gradually becomes a pinkish and finally a nearly white sandrock which is well known as a good building stone at Hinckley and on Kettle river. It seems that the eruptions that characterized the early portions of its history are marked by the fine red conglomerates, and by the red shales into which the conglomerates gradually change, and that, had it not been for this eruption, there would have been a continuous and uniform sandstone deposition from the pebbly conglomerate and white quartzyte at the bottom to the sandstones at Hinckley, and finally to the St. Croix sandstones of the Mississippi valley, which are characterized by an upper Cambrian fauna. At the earliest, therefore, these sandstones (at Fond du Lac) seem to fall into the bottom of the upper Cambrian, and it would be a convenient subdivision to adopt the Manitou eruptives of the Keweenawan as the plane of stratigraphic separation from the middle Cambrian. It cannot be questioned that such a disturbance of the oceanic waters would exterminate the species existing in the vicinity, and for a long time prevent the introduction of others.

The quartzyte and siliceous conglomerate lying below the Manitou eruptives may therefore be of the middle Cambrian, but this cannot be affirmed from the discovery of any fossils within the lake Superior basin.*

THE GABBRO.

The petrographic geology of the gabbro (rock No. 1) is given in volume v, and its general structural relations are to be found in the opening chapter of that volume.

*This subject is further discussed in the chapter devoted to the structural geology of the northeastern part of the state, in volume v.

At this place will be given some local details of the outcrops, which extend along the crests of the hills from Short Line Park to and beyond Duluth. Careful study of the gabbro has been made at Short Line Park and at Duluth. Most of the intervening space has not been examined with care.

Gabbro at Short Line Park. The Beaver Bay diabase. The Saint Paul and Duluth railroad, in passing from the upland to the level of the St. Louis river, between Short Line Park and Smithville, skirts closely along the western spur of the gabbro range, occasionally making cuts in the rock. The most important are near Short Line Park station, in the southern part of sec. 33, T. 49–15. Here, facing toward the west, is an abrupt cliff (Nos. 1942–1947), which ascends from near the railroad track to the elevation of about 1,100 feet, the culmination being in the form of a rather sharp peak, as it is viewed from the south. This westward face seems to be due to some faulting. It is nearly perpendicular, and the heavy beds of the gabbro, with its variations, are very apparent. The whole rock mass dips, or slopes, toward the south, and is cut at the lowest point by the grade of the railroad. In the face of the cut the rock appears nearly or quite homogeneous, of a gray color, rather fine-grained, separated by irregular joints that cause it to present a coarsely jagged aspect, and to quarry out in irregular large blocks. It is not appreciably different from numerous trap sheets that have the name diabase, and it has the ophitic structure. At the western side of this ridge, however, this rock (No. 1951) is amygdaloidal with zeolitic and chloritic amygdules in abundance; also has seams and irregular deposits that appear to be of heulandite, calcite, etc. Indeed, it is not distinguishable, at least outwardly, from much of the trap and melaphyr that occurs on the east side of the gabbro range at Duluth, or from that which occurs at Taylor's Falls.

At the second cut, which is on the east line of S. E. ¼ sec. 33, about half a mile further east, the same sort of trap-like gabbro is seen. This is a small cut. At the third cut, where the range comes down *en masse* toward the railroad is an interesting exhibition of gneissic and bedded structures in the gabbro. The road barely cuts it, but passes round the rock. The grand alternation here seen is represented by the sketch below.

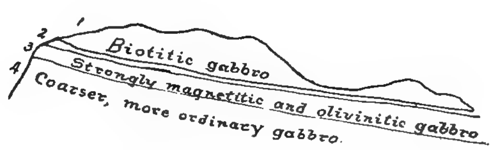


FIG. 108. SECTION NEAR SHORT LINE PARK LOOKING EAST NORTHEAST.

1—Ordinary biotite gabbro, 100 to 200 feet.
2—Fine-grained olivinitic gabbro (No. 1943), 10 feet.
3—Strongly magnetic, coarse, olivinitic (No. 1945), 15 to 20 feet.
4—Coarser, ordinary gabbro (No. 1946).

No. 2 weathers gray and greenish. One portion, which is marked by a green-weathered surface, is very fine grained, but black or nearly black within, and has a finer internal lamination which is hardly a stratification, but may be a fluidal struc-

ture. On the face of the exposed bluff the rigid beds or coarser laminæ which are about half an inch to an inch in thickness, are seen to be coincident with the general dip and strike, running on the face of the bluff from one end of the exposure to the other, with some interruptions where the rock is concealed.

No. 3 is most conspicuous, being thicker and black. When not crumbling, as it is frequently, with its coarse crystallization, it also is rigid in beds of about the same thickness as those in No. 2. It is strongly olivinitic, but all the crystals are coarser and apt to be superficially rotted to a rusty-yellow substance. This rusting of the olivine grains gives it a specked appearance. The iron varies from one-tenth to one-half or more of the whole, and endures the elements better than any of the other minerals. Black mica, with brilliant colors of yellowish irony red, is common, as well as pyroxene. Tabular plagioclases cut through the rock. The black aspect is due to the prevalence of menaccanite, pyroxene, olivine and biotite. Perhaps pyroxene should be placed first for frequency.

At another cut still further east there is a still larger display of similar olivinitic and magnetitic stratification.

If, now, a more careful survey be made of this rock, say at the first hill east of Short Line Park, we find that, in general, the amygdaloidal structure spreads widely over the gabbro. This is evident in ascending the hill. Numerous belts from three to six inches wide, of irregular course and shape, cross the face of the westward-looking cliff. These are distinguished by being much finer in grain and of darker color, jogging about suddenly and almost fading out. Some such narrow fine-grained belts are little dikes cutting the gabbro, but these do not jog about and do not fade out in the gabbro. They contain quartz amygdules, while the ropy belts contain calcite, chlorite and quartz, as well as a red mineral which is apparently orthoclase. The only place at which heulandite and stilbite are found is in a vein on the south side of the railroad cut, where the rock falls away in masses, sometimes obstructing the track. Here waters from above have acted, destroying the rock and converting some of it into a soft chloritic soapstone or shale, which is occasionally stained red by iron. Generally, in the cut, the rock does not show any amygdaloidal structure. This structure appears best at the west side and along the top of the cliff and widely over the general upper surface, as it rises toward the north, culminating in a sharp summit.

Going up this slope we find its course coincides roughly with the prevalent direction of the dikes that cut the Thomson slates, *i. e.* about north and south. The supposed amygdaloidal surface flows show their outcropping edges running in the same direction, also the little later dikes mentioned. These later dikes are conspicuously amygdaloidal with quartz. About half way up the hill an original

vesicular structure pervades the whole surface of the gabbro, the fillings being green, but sometimes also quartzose. Over on the east side of the ridge this original porousness descends to a depth at least of three feet in the mass of the gabbro. The rock is here seen to be denser in places, and the amygdaloidal surface slopes eastwardly from 6° to 10°. The top of the hill, while not amygdaloidal conspicuously is of a finer grained, trap-like gabbro. There are numerous benches in the latter part of the ascent, the whole rock being broken by distant jointing in a manner very similar to that at Taylor's Falls. These are not evidently formed by successive layers of diabase and amygdaloid, but on wide and careful inspection they are seen to be actually separable into a series of such alternations. Some are plainly thus bedded, the amygdaloidal streak being from twelve to eighteen inches wide, and sloping east or southeast at an angle of about 10°.

There is not apparently here an illustration of the rule that the surface of the flow is porous, and the lower portion massive, but the amygdaloidal rock is on both sides of a separating plane which has the appearance of being a flowage-contact plane. This indeed appears to be the case generally here, though there is sometimes, especially along the west face of the hill, where the rock breaks off about vertical, a rather conspicuous banding about a foot wide which is both finer grained and amygdaloidal, and more evidently belongs to the upper surface of an extended flow, and resembles the succession seen say at Agate bay, though less marked and less extensive. No geologist can clamber over the face of the bluff on the west side without being convinced that this rock originated by a succession of surface flows in the same manner as the later Keweenawan flows.

The later dikes that cut this rock run approximately north and south. They are from four to six or eight inches in width, usually, and are jointed conspicuously along their contacting surfaces transverse to their direction, and are frequently amygdaloidal, the amygdules being elongated, often parallel with the jointing. One larger dike, at least sixty feet wide (the east side was hid by soil and brush), running N. 15° E., is not amygdaloidal. This was certainly introduced after the gabbro was solidified. It is very fine and dense, but coarser toward the centre, and the gabbro along the contact is gneissic for two to four inches.

Some of the amygdaloid seen on the western face of this hill is quite similar to the large boulder (No. 1949) seen at Cloquet (see the chapter on the Carlton plate, No. 87). This occurs not far from the Saint Paul and Duluth railroad, but the belts are but twelve or eighteen inches thick, the red (orthoclase) mineral being very evident. Yet, in all this hill no red rock proper can be seen, and in this respect this hill differs from that next further east, where much of it appears. At the north side of sec. 32, T. 49–15, northwest from the railroad cut at Short Line Park station, where the high-

way crosses the creek, is a small outcrop of rock belonging to this gabbro series, containing large blobs of red rock in scattered patches (No. 2091), though less abundantly than the boulder above mentioned.

The amygdaloidal structure of this gabbro hill appears old. It has an indefinable aspect that differs from that of the later amygdaloids of the Keweenawan. The dependence of this on the gabbro is an indication of a similar relation of the amygdaloids at Duluth to the gabbro range adjacent, and goes to confirm the idea that the Cabotian eruptives made important surface flows and other accumulations, as well as enormous batholitic masses. The rock cut at Short Line Park station is probably in the same relation to the great gabbro mass as the Beaver Bay diabase, but cannot be separated geographically from the gabbro mass proper. Probably the only true Manitou rock to be seen here is the dikes (No. 1953) that cut this gabbro. The deep well at Short Line Park, whose record has already been given, passed through a series of amygdaloids below the base of the Potsdam conglomerate, which are supposed to be the representative of this amygdaloidal portion of the gabbro. They are Nos. 21 to 27, inclusive. Hence, the flow gabbro seen at Short Line Park may be considered the westward continuation of the Beaver Bay diabase.

The Cabotian at Duluth. Many very interesting features of the gabbro can be seen at Duluth and in the hills that rise in the northern and western suburbs. The rock is much exposed, and many of its features can be studied minutely, and its relations to the clastics and to the surface flows that occupy the lower levels could formerly be traced almost continuously. The interpretation of the geology of Duluth, here presented, is that which has grown up in recent years, based on a wider field of fact than can be observed within the limits of the city, and has been already outlined in giving the field characters that obtain at Short Line Park.* The gabbro itself is believed to be of the nature of a basic igneous intrusion that invaded the strata of the Animikie existing in the region, at the close of that formation. This great event is one of the evident steps in the history of the lake Superior synclinal, and probably it can be separately identified, as indeed has been indicated, on both sides of the lake. When the rocks of this intrusion did not reach the surface they profoundly affected not only the Animikie but also the older clastics. The heat that they carried fused the clastics, and the fused rock often flowed with the gabbro itself, and on congealing it also formed large bodies of a different sort of igneous rock, viz., the "red-rock" of the Cabotian so often referred to (Nos. 1B, 19, 42). These two rocks exhibit interesting relations. They occur in contact, not only as great bodies of massive rock, but they both flowed out at the surface, forming lavas and amygdaloids. When the fused clastics were rapidly cooled they gave rise

* Compare also *Amer. Geol.*: "A rational view of the Keweenawan." N. H. WINCHELL. Vol. xvi, p. 150.

to felsytes and aporhyolytes, and to quartz-porphyries; when they had sufficient time they consolidated as granite and augite-syenyte. The vents at which the surface rocks may have escaped as from volcanoes cannot be certainly located, but they must have been in the immediate vicinity of the greater gabbro bosses. They were probably directly above those great gabbro bosses, which then were great reservoirs from which the molten rock flowed, but all the crater-like features have been eroded and the natural surface so degraded as to expose the reservoirs themselves.

As the Animikie was greatly fused at the loci of the greater disturbance, it was greatly broken, and, at points more removed from those loci, more or less mingled with the result of its own fusion. At still more protected places it was simply metamorphosed (No. 44), though much tilted. In such cases it can be seen to acquire in one direction the characters of the red rock, and in the opposite direction those of the normal Animikie (compare the Pigeon Point plate). The actual surface eruptives that buried the tilted and broken Animikie strata are preserved from denudation only at lower levels. They occur all along the lake shore from near the Union depot to Chester creek and further east. In some cases they are mingled with volcanic debris. There is a sandstone (No. 17) at the lake shore inter-stratified with those surface flows, which consists essentially of fragmental devitrified glass with a few angular quartz grains. The acid quartz-porphyries at New London (No. 55) are a portion of the acid flows derived from the fusion of the clastics by the heat of the gabbro intrusion (figure 109). The porphyrytes and amygdaloidal

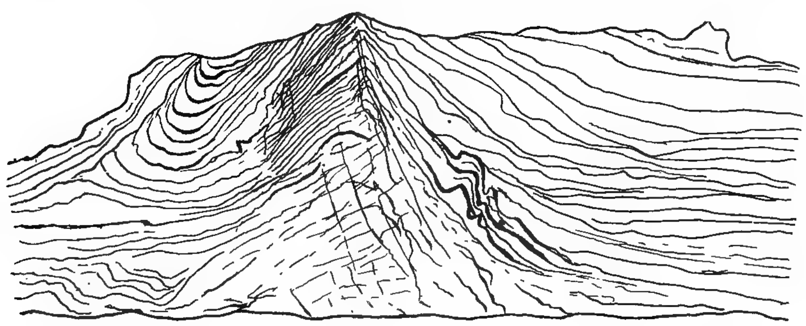


FIG. 109. STRUCTURES IN THE RED ROCK BLUFF AT NEW LONDON.

porphyrytes, and the diabases that occur within the city of Duluth at the lake shore are but little or not at all affected by the intermixture of the acid with the basic elements. There are but few places where these elements can be seen to be mixed with a regularity approaching complete interpenetration. Where they are so mingled (as in No. 5) the resultant rock, when cooled slowly, is a massive, wholly crystalline one, which is intermediate between gabbro and granite. It has been styled "hornblende gabbro" by Streng and Kloos and "orthoclase gabbro" by Irving. But more frequently there are strings and patches of the acid (red) rock disseminated

through the otherwise homogeneous gabbro (compare plate DD, figure 1). Such can be seen at some of the cuts made for the streets in the gabbro back from Rice's point and eastward. Sometimes the red rock appears to exist as dikes in the gabbro and also to underlie the gabbro in enormous masses. In general the acid elements penetrated the basic with greater facility than the basic the acid. But that they were molten at the same time, and became more or less mingled, is evident from many minor associations that they exhibit.

The best place to examine the unmodified gabbro is at the cuts in the vicinity of Rice's point. The "red rock" variety becomes strictly granitic, at Duluth, but when it is intimately mingled with the basic, its elements are seen to crystallize as orthoclase, hornblende and quartz, in quite sizable grains (No. 5). In such conditions the labradorite of the gabbro is also apt to be penetrated by micro-graphitic quartz, and so obscured by it and by other secondary products that it can hardly be determined as labradorite. Sometimes also epidote and sphene result, while the augite is apt to become fibrous and the olivine (which is not common) to wholly disappear. In other places the contacting on the clastics is evinced apparently by a greater amount of menaccanite in the vicinity. Some years ago there was some effort to develop this iron ore economically, at a point in the northern part of the city. The largest exposures of the red rock at Duluth are in the form of a more or less continuous belt, running east and west on the slopes of the hills about 250 feet above the lake. This belt, which can be traced for several blocks, is of irregular width, and sometimes rises as high as about 400 feet. It gives the general impression of a sheet of varying thickness lying against the gabbro range and occasionally penetrating it in favorable conditions. There are no surface eruptives above it (*i. e.*, at greater elevation), but in the line of its extension is found an unfused portion of the Animikie (No. 44). This last is found on Piedmont avenue at its intersection with Lake street, and along Piedmont avenue toward the west. Here are large and interesting exposures of some supposed Animikie slates, hardened and modified by the gabbro, making a more or less mottled, fine-grained, dense and black rock (Nos. 1966 and 1967). Outwardly it frequently presents the aspect of a coarse conglomerate partially fused and cemented, but it is more probable that such appearances are due to the effect of the metamorphic action on the slates. A little west from this crossing, where a small creek passes Piedmont avenue, the red rock (No. 1968) is in the bed of the creek, and above it, in the roadway, is this black rock. West from the crossing of the creek, this black rock continues interruptedly for two or three blocks, but with variations to the red. In one place, just west of the creek, the red rock has a perpendicular line of contact on the black. This red rock is homogeneous, or nearly so, very fine-grained, though having

sparse crystalline cleavages of a porphyritically scattered very fine feldspar. It also has dark-green, fine specks which seem to be closely embraced in the integral structure of the rock. The black rock (No. 1966) is usually rather homogeneous, and densely fine-grained, resembling a fine basalt, but on the weathered surface, nearly everywhere, it is revealed as not being a homogeneous rock (No. 1967), for curiously shaped forms weather out, often appearing like foreign boulder-like pieces, or sometimes of irregular shapes like a breccia. Yet it can hardly be called a breccia for this structure pervades a considerable thickness, and a large area. Indeed, the whole of this rock here exposed is, so far as can be seen, affected more or less by this structure. In thin section this rock shows a clastic origin, with scattered angular fragments of quartz, the most of the fine matrix being sometimes unidentifiable, but showing magnetite and mica. There is also apparently some chlorite and calcite. In the field it would be very easy to confound this fragmental black rock with an eruptive, dense basalt, for they both occur at Duluth. These general relations are shown by the profile sketch (figure 110).

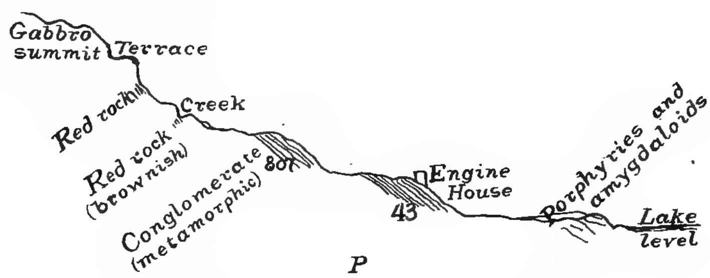


FIG. 110. PROFILE SKETCH AT DULUTH.

A still more conglomeratic aspect is to be seen on a low knob farther west and at a higher elevation. This knob is one of a series of undulations east of the creek which is ponded artificially above the terrace boulevard, and west of the inclined railway, *i. e.*, nearly northwest from the Union depot. Here there appears to be two rocks, one red and the other black, but the red color is often only superficial, and about an inch thick, the same rock being nearly black below. These reddened areas are surrounded by narrow bands or seams of dark rock which give them the appearance of boulders embraced in a matrix. On some parts of the exposed area the red rock is in irregular patches and veins in the black, appearing as if it had filled many minute fractures in the black rock, embracing the black as if it filled the openings in the breccia of the black. When one notices closely, however, he observes that these characters are not invariably dissociated to their respective rocks. The black fades out to the red by the appearance of red blotches throughout it, and in some cases a red surface is underlain by a dark brown interior, and this again becomes black. In other places there is a sprinkling of the red element evenly through the black, becoming apparent on weathered surfaces, though such rock is usually, or

always, a massive and compact one which has cooled from fusion. In short, the two rocks are not essentially different.

Further east, in the vicinity of the High School, were formerly numerous exposures of a similar conglomeratic looking rock extending in a series northeast and southwest as if in the strike of a sedimentary formation. This lies below a thick diabase (No. 43) which extends to the falls of Kinichigaquag creek (Chester creek); it has a rough blotched exterior, and appears like a fine basalt, in general, but shows light quartzose nodules, somewhat micaceous. The most of the pebbles are of the color of the rock except on weathering. In other places, by reason of the weathering and the fires that have prevailed, a red banding is seen rudely conformable with the supposed bedding, which, on being broken, reveals a texture and fracture as well as color and hardness of the quartzytes at Pigeon point. Rock No. 807 represents this gray quartzyte, but not the general character of the rock that resembles outwardly a breccia or conglomerate. Underlying this supposed conglomerate is a red quartzless rock or red syenyte. This occurs in irregular patches and extends westward to Rice's point.

In attempting to account for this apparently conglomeratic character in a rock which was not probably originally a conglomerate, there is available, apparently, but one explanation, viz.: a breccia mingled with the fused parts of itself. Such breccia would lose its angularity by the friction of its parts upon themselves, or by the solution of the angles and edges in the molten rock that filled the openings. Considering the circumstances under which this metamorphism took place, it is to be presumed that the clastic rocks were frequently and profoundly brecciated, and that the openings were filled sometimes by basic magma and sometimes by acid.

The Cabotian surface rocks are those that appear, or did formerly, along the lake shore from near the Union depot eastwardly. By the development of the city their exposures have nearly all been concealed. They consist of diabase and porphyrytes, the latter being very often amygdaloidal. A fair illustration of these rocks can still be seen at the mouth of Chester creek (Nos. 35, 36), and for some distance up the creek, which runs in a little gorge which has been eroded in them. They have decayed considerably and are easily excavated. Some of them are dense and nearly black, evidently once in a condition that was more or less glassy, making a basalt. They also embrace some beds that are fragmental, though consisting almost wholly of eruptive materials. The stratiform condition of this clastic material indicates the presence of the ocean and its dissemination of the debris at the date of the eruptions. It is a submarine volcanic tuff mingled with ordinary detritus. In the midst of these strata sometimes occur, rather irregularly, areas of coarse gabbro-like rock, the exact order and manner of occurrence of which cannot be stated because

of the surface covering. Such coarse rocks are seen at the following places: Between Second and Third streets and Third and Fourth avenues west, behind the Methodist Episcopal church—the old church—(No. 49); at a street cutting to the east of the base of Minnesota point on Superior street, this cutting furnishing good quarrying facilities. These rocks are either parts of unusually heavy surface flows from which the amygdaloidal upper portions have been removed by glacial abrasion, or they are local protrusions of the main gabbro mass in spurs somewhat more distant from the chief reservoir amongst the Animikie beds, now uncovered by the removal of the superincumbent strata.

On Michigan street the grading has exposed a condition of the gabbro not common. The entire mass of the rock is separated into globular masses of about an inch in diameter, causing it to appear fragmental (plate P, figure 1). This globular structure, further west, is more coarse, and is represented by rock No. 1D.

Lastly, these Cabotian eruptives, as well as the gabbro, are cut by a series of later dikes, which have a prevalent direction nearly north and south, in that respect repeating or continuing the dike system seen at Thomson and at Short Line Park. These dikes are of diabase, and entered the rocks that they cut after those rocks had cooled, which is evinced by the fineness of the grain of the dikes at their contacts, and they are believed to belong to a later eruptive epoch, *i. e.*, that which, in order to distinguish them from the earlier, may be called Manitou, and which followed the formation of the pebbly quartz conglomerate of the St. Louis valley.

ROCK SAMPLES.

The following rock numbers were collected in this area:

By N. H. Winchell: Nos. 1-61; 443-448; 511-514; 807-809; 850; 853-853B; 856, 857; 1540-1545; 1796-1806; 1942-1948; 1950-1954; 1966-1968; 2089-2091.

By J. E. Spurr: Nos. 188S-198S.

By U. S. Grant: Nos. 925G-928G.

CHAPTER XXXII.

MINNESOTA IRON MINING ECONOMICALLY AND STATISTICALLY CONSIDERED.

By HORACE V. WINCHELL.

"Ce n' est pas l'or, mais le fer qui est le roi des métaux."

Minnesota's one-sided and unequally developed iron industry is of recent date, but phenomenal growth. Though only a decade and a half since the first car load of ore was digged from its rocky bed in our northern wilds, the infant industry has grown with amazing rapidity, until today an almost incessant stream of purest hematite is kept moving toward the insatiable and ever more numerous furnaces of the east, and thousands of human mouths depend for daily bread upon the steady and profitable operation of the various forces here engaged in furnishing the raw material for the iron and steel structures of the world. Should the sources of this great supply for raw iron suddenly become exhausted, the consequences are beyond the power of pen to portray. From east to west, from north to south, great industrial enterprises would immediately become benumbed. Mills, factories and centres of activity would be silenced, and the prices of the commonest articles of iron would rise to such a figure as to cause many a failure, and perhaps a wide-spread panic in money centres.

To describe briefly for the citizens of Minnesota, from the view-point of one who has been more or less intimately connected with this iron-mining industry from its inception to the present time, and to represent in as few words as possible the importance of properly nourishing and prolonging its existence for the greater benefit of the Commonwealth, is the purpose of the writer in the pages that follow. Much that he will say has been already presented in one way or another by himself or others; but it is incorporated here as the proper place in which to record events and information that are of so great importance in the past and future of the state.

In 1880 the population of St. Louis county was 4,504. There was not a settlement north of Duluth and the wilderness that lay between lake Superior and the Ontario line was known only to a few explorers and Indians. The gold mining excitement of 1866 had died out, and only vague recollections of Vermilion lake lingered

in the minds of those who had been led to visit what is now known as the Vermilion Iron range by the exaggerated reports of gold ore there. Samples of iron ore of the red hematite variety had, it is true, been collected there in early days, and the state geologists had called attention to the evidently large deposits of this mineral at various times since the days of Norwood and Eames. But the region was so remote and so little known, and the reports of geologists are so little read by the explorer and miner, that no attention was paid to the vast stores of iron treasure, and no one dreamed of the developments so close at hand.

In 1890 the population of St. Louis county had reached 44,862. In this year the production of iron ore, which began in 1884, was 880,014 gross tons. A standard gauge railroad had been constructed to Tower and Ely and the Vermilion range had taken its place among the prominent iron ore districts of lake Superior. Millions of dollars had been invested in appliances for the mining and handling of iron ore, and thriving cities had been established at the mines, and at Two Harbors where the ore is transferred from railroad car to vessel.

In 1895 the population had increased to 78,575. The Mesabi range had been discovered and opened up and the output of ore from this wealthy county reached the magnificent total of 3,859,425 gross, or considerably more than 4,000,000 net, tons of high-grade hematite ore.

In the year 1898 the iron ore production had increased to nearly 6,000,000 tons, and the increase in population, due to the settling up and development of new districts, had kept nearly an equal pace.

It is not possible to determine the exact relation between increase of population and the growth of this iron mining industry; but the figures given above are interesting and significant, and it is difficult to escape the conclusion that there is a relation of mutual dependence between them. If, then, the mere opening up and exploitation of iron mines bring in their train such rapid growth, how much greater would be the benefit from the establishment of industries to work this product into its various refined and finished forms? If the development of an iron mining industry could add thus suddenly to the population of a district, how much more rapidly would that district become depopulated if the industry which supported it were suddenly paralyzed! Many examples of the decay or utter abandonment of mining towns have come under the writer's notice in the western states, and nothing more desolate can be imagined. To properly conserve, therefore, and to prolong the existence of this important industry, should be the endeavor of every one who has the welfare of the State at heart.

GEOGRAPHICAL.

Location of mines. As already indicated, the iron mines of Minnesota, so far as developed, are situated in St. Louis county. About midway between lake Superior on the southern side and the Canadian boundary line on the northern side of this small empire, with its area of 5,860 square miles, are found the two iron belts or ranges, lying about twenty miles apart from each other and extending in an easterly and westerly direction. On the south, and hence nearer to lake Superior and the ore shipping ports, is the Mesabi range, whose rocks may be traced by surface out-croppings from T. 65–4 W. to T. 56–24 W., a distance of more than 150 miles. The iron ore formation of the Vermilion range is not nearly so regular and well defined; but the rocks of that general formation are known to extend from T. 65–7 W. to T. 60–26 W., a distance of more than 125 miles.

It should not be imagined that there is one continuous deposit of iron ore stretching across the great extent of country mentioned above. On the contrary the ore deposits are scattered along in groups at irregular intervals, and thus, besides being very narrow as compared with their length, the ore belts are chiefly composed of non-productive or unmerchantable reaches for miles, with occasional groups of rich mines. Thus on the Vermilion range there have as yet been discovered but two groups of mines, situated respectively at Ely and Tower, twenty-three miles apart, and the remainder of the range is not definitely known to possess workable deposits. On the Mesabi range the groups of mines are centered around the cities of Biwabik, McKinley, Sparta, Eveleth, Virginia, Mountain Iron and Hibbing.

HISTORICAL.

The first mention of iron ore in northern Minnesota, appears in the report of J. G. Norwood, under date of 1850.* He mentioned the occurrence of iron ore at Gunflint lake, on the extreme eastern end of the Mesabi range, and correctly stated it to be in the eastward continuation of the hills known farther west as the Mesabi, and which extend to Pokegama falls on the Mississippi river. No particular importance appears to have been ascribed to this ore by Norwood, and in truth it has none at the point where he observed it.

H. H. Eames, state geologist of Minnesota in 1865 and 1866, was the first to observe and report iron ore on both the Vermilion and Mesabi ranges, and to consider it of any value. In his report for 1866, he describes the ore outcroppings near the southern shore of Vermilion lake, and in his report published the following year is an account of the ore at Prairie River falls, on the western end of the Mesabi, and several analyses showing it to be of good quality.

* D. D. OWEN's report of a geological survey of Wisconsin, Iowa and Minnesota, p. 417.

The later geological reports of Minnesota have so frequently mentioned and described in detail the iron ranges and the early development that it seems unnecessary to go over it again here. The well-informed members of the community are always ready to award to the state geologists the credit due them for so early and in such a singularly accurate manner foretelling the probable developments of these great iron ore districts. That similar recognition is also received from outside students and recognized authorities on the subject is evident from the following quotation from the report of Mr. John Birkinbine, statistician for the U. S. Geological Survey, who in his report for the year 1896 speaks as follows:

"The Geological Survey of Minnesota is to be congratulated upon having pointed to the region now known as the Mesabi range as a probable iron-producing district prior to active explorations and exploitations, and the limits in which workable bodies of commercial ore have been found correspond closely with the conclusions arrived at by the geologists as to the probable existence of this material."†

QUALITY OF ORES.

As handled and sold at present the price of iron ore depends on its chemical and physical properties to a greater extent than ever before. The ore is sampled at the mine and often at the docks of both the shipping and receiving ports, and if there is any variation in chemical composition from that guaranteed when the ore is sold, there is a corresponding reduction or increase in price. The table which accompanies this chapter gives the analysis of all the lake Superior iron ores for the season of 1898. From this table it will be seen that the ores of the Mesabi range average higher in iron and lower in phosphorus than the ores of any of the Michigan ranges. It will also be seen that the Vermilion range ores contain a higher per cent of iron than those of any other range.

If therefore chemical composition were the only criterion, the Minnesota ores would bring higher prices than those from any other range. As a matter of fact, however, the physical quality of an ore affects its behavior in the blast furnace, and hence its desirability. Thus it is found in practice that the extreme fineness of the Mesabi ore renders impracticable its use in furnace mixture with other ores to a greater extent than forty per cent. This fact, added to that of great abundance and easy production, operates to depress the price of Mesabi ores, even though their chemical make-up is superior. The result is that ores which on the whole average better than those from any other district in the world bring at present the very lowest price in the markets.

Attention should perhaps be called to the fact that there is an immense quantity of poorer grade ore on the Mesabi range, which will not bear the expense of shipping to far distant markets, and which will not be mined for anything but local consumption as long as iron ores sell at the present low figures.

† *Seventeenth Annual Report U. S. Geol. Sur.*, part iii, p. 33.

The Vermilion Range ores, however, besides being very high grade, possess desirable physical properties, and bring almost the best prices in the market. Indeed, the output of these ores is much below the demand, and new mines are being constantly sought for at great expense. Such a mine as the Chandler, with its large body of granular and uniformly high grade ore, is rarely known, and its ores bring a premium each year.

ANALYSIS OF LAKE SUPERIOR IRON ORES, 1898.

Gogebic range.

ORE	Iron, Natural State	DRIED AT 212° FAHRENHEIT.									Moist.
		Iron	Silica	Phos.	Mang.	Alumina	Lime	Magnesia	Sulph.	Org. and Vol.	
Anvil*	....	62.74	4.09	.055	.82	.92	.47	.11	.018	....	12.36
Anvil, East vein*	....	61.00	5.25	.058	2.18	.86	.05	Trace	.014	....	12.75
Ashland	55.44	63.19	3.96	.036	.25	2.21	.21	.15	.015	3.00	12.27
Atlantic	55.63	62.89	4.29	.047	.86	1.49	.18	.15	.021	3.25	11.54
Aurora	55.35	61.34	6.72	.028	.40	1.02	.27	.11	.018	4.12	9.77
Best	50.34	58.00	10.25	.0616	.81	1.83	.31	.16	.013	3.28	13.20
Brotherton*	55.60	63.00	7.20	.035	.47	.87	.21	.04	.018	1.00	11.74
Buckeye	53.08	59.44	8.40	.071	.423	1.526	.24	.266	.013	4.76	10.70
Cary Empire	52.99	58.21	3.22	.059	4.50	.80	.27	.14	None	5.60	8.96
Cary Manganese	....	56.08	....	.056	6.52	....	....	....	....	....	10.06
Colby No. 1	51.58	56.70	3.20	.066	6.820	.880	.160	.400	.006	2.200	9.02
Colby No. 2	54.66	60.60	4.00	.080	2.25	1.10	.17	.47	.008	2.15	9.80
Cromwell*	....	60.00	3.75	.032	3.10	.75	.10	.13	.010	....	9.58
Day	56.80	63.58	3.11	.078	.3319	....	....	....	....	....	10.67
Eureka	....	61.65	6.75	066	.140	.95	.52	.22	.011	....	9.80
Fairfax	55.24	64.05	3.00	.0728	.9915	....	....	....	....	....	13.76
Globe	55.20	62.02	3.93	.095	.21	1.70	.35	.15	.010	3.25	11.00
Iron Belt	53.74	60.75	8.09	.041	.40	1.21	.11	.18	.024	3.09	11.54
Lawrence	56.04	62.28	5.64	.059	.552	1.126	.11	.135	.006	3.86	10.02
Melrose*	55.39	62.00	4.92	.030	1.11	.81	.07	.10	.018	3.90	10.66
Montreal	60.56	66.00	2.31	.040	.36	.71	.23	.09	.007	1.90	8.24
Mikado	....	59.15	....	.044	....	....	....	....	....	....	13.00
Newport No. 1	48.71	54.05	4.60	.037	8.01	1.20	.15	.07	.006	5.50	9.87
Newport No. 2*	45.00	50.00	....	.035	6.00	....	....	....	....	....	10.00
New Era	50.80	57.00	12.15	.026	1.26	1.05	.47	.11	.005	3.59	10.87
Norman (Palms)	53.94	62.00	4.61	.085	.84	1.29	.23	.17	.014	3.67	13.00
North Vein	56.29	62.37	4.10	.046	.540	.890	.620	.090	.004	2.240	9.75
Norrie	56.56	63.08	....	.0388	.3888	....	....	....	....	....	10.34
O'Brien	....	58.98	12.50	.101	....	....	....	....	....	....	13.85
Palms	53.92	62.95	3.94	.055	.90	1.17	.16	.14	.017	3.53	14.34
Pearce*	....	58.60	11.44	.062	.64	.81	.22	.13	.014	....	7.60
Pence*	....	65.20	5.50	.019	.24	.28	.15	.05	.014	....	....
Rand	52.74	58.57	5.25	.036	3.21	1.07	.66	.60	.017	....	9.95
Shores	58.87	64.28	3.30	.029	.30	.75	.18	.11	.004	1.12	8.42
Sunday Lake	....	63.09	8.60	.027	.39	.90	.36	.19	.010	....	10.54
Tilden	54.83	63.43	....	.046	1.0902	....	....	....	....	....	13.56
Toronto	44.83	49.00	26.00	.040	.45	1.25	.40	.25	.015	....	8.50
Windsor*	....	64 00	4.00	.045	.63	.80	.31	.10	.008	....	....
Average	....	60.41	....	.051	....	....	....	....	....	....	....

Menominee range.

ORE	Iron, Natural State	Iron	Silica	Phos.	Mang.	Alumina	Lime	Magnesia	Sulph.	Org. and Vol.	Moist.
Amasa	53.34	56.00	6.98	.267	.35	3.35	1.90	1.74	.014	4.90	4.75
Appleton*	....	63.30	4.61	.018	.27	1.30	.52	.47	.019	....	8.50
Aragon	59.10	63.24	4.39	.036	.14	1.01	.89	1.84	.007	1.28	6.54
Badger	54.21	59.73	4.18	.146	.443	2.72	1.10	3.22	.075	2.70	9.24
Bristol*	52 08	56.00	3.75	.80	1.25	1.10	3.60	1.50	.030	....	7.00
Castile*	....	65.63	3.23	.011	.18	1.19	.35	....	.010	....	6.42
Chapin*	57.39	61.60	4.96	.065	.32	1.15	.61	2.20	.012	2.27	6 34
Clifford	39.42	40.44	39.19	.016	.11	.85	.51	.26	.002	.70	2.51
Columbia	53.40	60 00	3.78	.550	.23	1.99	.41	.80	.100	....	11.00
Commonwealth*	....	60.00	4.75	.22	.75	1.65	1.40	1 20	.15	....	6.25
Crystal Falls	53.62	58 60	4.45	.795	.20	1.41	2.40	.93	.008	2.140	8.50
Davidson	51.37	56.39	6.25	.166	.395	3.12	1.50	3.49	.114	3 90	8.90
Dunn	52.66	58.00	4 00	.582	.74	1.98	1.72	.81	.031	6.22	9.20
Elmwood	53.14	58.16	5.69	.165	.331	2.804	1.18	2.317	.055	4.62	8.63

* Expected analysis for 1899. All others are the average for 1898.

Menominee range.—Continued.

ORE	Iron, Natural State	DRIED AT 212° FAHRENHEIT.									Moist.
		Iron	Silica	Phos.	Mang.	Alumina	Lime	Magnesia	Sulph.	Org. and Vol.	
Florence	51.62	56.10	4.79	.388	.31	2.18	1.17	1.92	.271	5.67	7.98
Granada	57.80	62.42	4.56	.062	.18	1.03	.54	1.60	.017	1.70	7.40
Great Western	56.15	61.30	4.60	.375	.24	1.16	2 10	.80	.006	3.10	8.40
Hemlock	56.68	59.43	5.60	.302	.14	2.22	2 10	1.75	Trace	2.33	4.62
Hiawatha	....	61.60	3.65	.13	.27	1.35	.93	.27	.082	....	6.00
Homestead	....	54.87	4.68	.086	.38	2.05	3.48	4.87	.003	....	....
Iron River	....	59.80	5.29	.356	.37	3.41	.69	.37	.028	....	9.50
Keel Ridge*	39.46	40.64	37.42	.046	.20	.90	1.35	1.00	.006	1.50	2.90
Lamont*	52.70	57.60	4.15	.72	.24	1.24	2.61	1.10	.006	2.10	8.50
Lerida	58.80	63.48	3.74	.152	.137	1.15	.94	1.67	.003	1.05	7.37
Lincoln*	56.85	62.20	4.70	.425	.320	1.670	1.420	.720	.010	2.840	8.60
Loretto	53.13	58.50	9.80	.019	.24	1.92	.32	.29	.139	2.66	9.17
Mansfield	....	63.36	4.14	.044	.38	1.97	.46	.23	.019	....	11.00
Mastodon	58.23	61.78	2.20	.55	.15	2.40	.70	.20	.085	5.10	5.75
Millie	59.75	63.21	2.54	.027	.20	.93	1.14	1.74	.009	2.51	5.48
Nimick*	58.05	62.68	4.37	.078	.17	1.05	.64	1.62	.013	1.68	7.39
Paint River	....	56.40	3.48	.502	.37	6.12	5.58	.71	.068	....	8.00
Pewabic*	58.90	63.59	4.32	.012	.13	1.05	.91	1.22	.002	1.46	7.38
Pewabic Genoa	42.14	44.00	32.89	.007	.09	1.10	.79	1.07	.005	1.18	4.22
Rex	53.51	57.54	6.26	.066	1.08	1.52	1.24	3 93	.018	3.36	7.00
Russell	52.40	56.35	6.72	.065	.30	2.21	2.37	3.48	.053	3.78	7.00
San Jose	60.62	65.51	3.46	.0135	.25	1.14	.19	.25	.036	.73	7.47
Sheridan	....	58.50	6.50	.130	.50	4.00	.60	.70	.250	....	9.12
Star	58.02	62.29	4.80	.085	.31	1.35	.62	1.51	.007	1.95	6.86
Toledo	50.61	54.00	18.23	.010	.18	.65	1.20	1.57	.003	....	6.28
Tyrone	....	62.00	3.91	.106	.19	.72	1.50	1.90	.003	....	....
Average	....	58.65	....	.215	....	....	....	....	....	....	....

Marquette range.

ORE	Iron, Natural State	Iron	Silica	Phos.	Mang.	Alumina	Lime	Magnesia	Sulph.	Org. and Vol.	Moist.
Angeline, Hard	63.66	66.89	2.25	.013	.09	1.27	.11	.04	.014	.50	4.83
Angeline, Hematite	59.14	65.37	2.69	.041	.30	1.05	.12	.08	.018	2 01	9.53
Angeline, South	54.60	62.17	4.75	.135	.27	1.63	.25	.15	.020	3.68	12.17
Barnum*	....	65.50	3.49	.075	.36	1.80	.32	.26	.026	....	.89
Beacon*	....	46.00	29.75	.045	.07	2.50	1.00	.80	.030	....	.84
Bell	40.25	41.18	37.22	.030	.18	1.04	.09	.12	.031	1.62	2.26
Blue*	....	63.40	5.20	.12	.25	1.96	.55	.72	.010	....	10.50
Buffalo*	....	61.80	6.60	.13	.55	1.84	.86	1.16	.003	....	13.50
Buffalo, South*	....	61.95	5.70	.115	.39	1.75	.92	.71	.005	....	10.90
Cambria	55.34	61.80	6.70	.051	.280	1.900	.970	.340	.008	2.120	10.45
Cambridge	51.91	62.04	5.78	.192	.100	.142	1.66	.88	.002	1.37	16.32
Champion No. 1*	64.35	65.00	4.59	.055	.09	2.27	.96	.66	.007	....	1.00
Cleveland Bessemer	66.80	67.09	2.25	.028	.10	1.20	.23	.28	.024	.28	.43
Cliffs Shaft	61.82	62 50	3.40	.107	.37	1.86	1.34	1.12	.027	2.20	1.08
Dartmouth*	65.00	65.75	2.52	.032	.18	1.74	.32	.11	.014	.32	1.14
East End Bessemer*	....	61.06	7.48	.046	.33	2.09	.23	.30	.014	....	10.33
Essex*	59.40	60.00	10.25	.110	.30	2.20	.53	.20	.020	....	1.00
Foster	49.58	51.45	18.45	.142	.27	1.10	.18	.39	.020	5.18	3.63
Harvard Bessemer*	56.89	65.00	3.15	.050	.31	1.78	.32	.18	.020	2.09	12.48
Humboldt*	....	65.90	3.91	.15	.13	1.88	.88	.24	.020	....	....
Ishpeming	51.08	59.52	6.75	.067	.48	2.18	.22	.40	.010	4.17	14.18
Jackson Pit 7	52.70	55.21	13.71	.067	....	3.25	....	....	....	....	4.55
Jackson Hard, No. 2 Bess*	48.56	50.01	24.23	.047	.15	2.93	....	....	'02	....	2.90
Jackson, South Side	....	42.56	33.71	.040	1.98	1.58	....	....	....	....	9.79
Kenyon*	46.10	52.00	18.00	.110	.71	1.22	.30	.19	.027	3.83	11.34
Lake	51.69	60.00	5.79	.088	.71	2.70	.35	.67	.019	4.43	13.85
Lake Bessemer*	56.12	64.21	3.98	.038	.52	1.51	.23	.15	.023	1.80	12.59
Lake Bessemer, East End*	53.74	61.00	7.40	.043	.42	2.17	.28	.16	.023	2.71	11.90
Lake Silica	42.86	48.16	25.17	.039	.43	1.69	.36	.47	.035	1.65	11.00
Lake Superior No. 1*	64.25	65.00	3.64	.094	.31	2.14	.37	.36	.013	.49	1.16
Lillie	55.43	62.56	5.40	.074	.39	1.97	.34	.11	.008	3.120	11.40
Manganiferous Hematite*	48.67	54.29	7.20	.071	4.61	2.20	.82	2.57	.025	....	10.35
Marquette	39.26	41.06	36.85	.055	.30	1.07	.20	.16	.020	1.67	4.37
Michigamme*	....	66.50	4.67	.13	.23	.07	.25	.62	.050	....	.75
Missabe Friend*	....	39.54	....	.020	....	....	....	....	....	....	.92
Negaunee	55.76	62.65	4.31	.056	....	2.83	....	....	....	....	11.00
Negaunee Non-Bessemer	53.40	60.00	4.31	.115	....	2.83	....	....	....	....	11.00
Norfolk*	55.52	56.00	13.43	.055	.11	3.18	.71	1.05	.030	....	.85
Old Mine Hematite, Bess.	54.98	63.16	4.17	.067	.49	2.00	.30	.28	.020	2.78	12.95
Old Mine Hem., Non-Bess.*	53.36	61.00	5.50	.101	.75	2.00	.48	.59	.027	2.99	12.52
Oxford*	....	64.50	4.40	.076	.32	1.80	.25	.23	.013	....	1.15

*Expected analysis for 1899. All others are the average for 1898.

Marquette range.—Continued.

ORE	Iron, Natural State	DRIED AT 212° FAHRENHEIT.									Moist.
		Iron	Silica	Phos.	Mang.	Alumina	Lime	Magnesia	Sulph.	Org. and Vol.	
Peninsula	......	59.00	7.38	.11	.30	3.48	.75	.94	.012	......	14.64
Platt*	......	58.70	......	.038	......	......	......	......	......	......	8.75
Princeton*	54.09	64.92	3.16	.055	.73	.159	1.12	.742	.001	1.20	16.68
Prince of Wales*	......	61.55	6.10	.12	.36	1.72	1.40	.46	.012	......	13.00
Queen	53.51	61.40	5.56	.150	.294	2.623	.45	.468	.010	2.90	12.85
Regent	......	61.47	7.71	.064	.22	2.33	.76	.17	......	......	13.47
Republic Special	66.78	67.07	2.80	.018	Trace	.71	.10	.08	.016	......	.43
Republic Specular	66.21	66.74	2.70	.034	.18	1.00	.17	.11	.011	.29	.79
Republic Kingston*	63.46	64.00	6.13	.034	.23	.82	.31	.209	.032	.045	.84
Republic Magnetic*	......	69.00	2.05	.040	.12	.48	.32	.14	.031	......	1.00
Rose	54.40	61.40	6.40	.120	.370	1.800	.420	.110	.008	3.220	11.40
Richmond	43.05	43.60	36.20	.034	.040	.640	.490	.110	.004	2.740	1.27
Salisbury	53.48	62.50	4.44	.117	.31	1.77	.38	.13	.013	4.13	14.43
Salisbury Bessemer	54.12	63.60	3.43	.044	.25	1.38	.13	.18	.017	4.45	14.91
Salisbury Silica	42.99	49.60	23.28	.050	.33	1.75	.18	.20	.021	3.11	13.33
Savoy*	60.08	61.00	9.11	.097	.32	1.97	.45	.39	.020	1.07	1.50
Sec. 16, No. 1 Bessemer	62.23	65.26	4.70	.022	.18	1.59	.29	.22	.015	.50	4.64
Sec. 16, No. 2 Bessemer	60.45	62.06	8.32	.032	.18	1.71	.34	.24	.015	.58	2.59
Sec. 16, New Shaft*	......	64.50	5.43	.035	.27	1.49	.27	.18	.016	......	2.08
Sec. 21, Hematite*	54.53	61.50	6.15	.147	.46	1.29	.48	.20	.027	3.25	11.34
Sheffield	60.05	61.48	9.12	.024	.24	1.82	.13	.08	.024	.55	2.33
Tilden Silica	41.07	41.90	38.30	.033	.10	.82	.19	.13	.018	.65	1.97
Volunteer*	......	57.79	12.46	.069	.20	2.23	.29	1.73	.019	......	1.50
Winthrop*	......	61.25	6.88	.135	.71	1.34	.44	.38	.027	......	11.37
Average	......	59.55	......	.073	......	......	......	......	......	......	......

Mesabi range.

ORE	Iron, Natural State	Iron	Silica	Phos.	Mang.	Alumina	Lime	Magnesia	Sulph.	Org. and Vol.	Moist.
Adams	57.91	64.03	2.92	.032	.48	1.06	.17	.18	.023	3.25	9.56
Admiral	59.21	63.80	5.10	.027	.320	.590	.220	.142	.004	2.110	7.20
Ainslie	58.23	63.46	3.29	.063	.41	2.38	.21	.12	.008	2.85	8.24
Auburn	58.45	64.65	3.05	.045	.35	1.78	.53	.18	Trace	2.18	10.00
Audrey	55.68	63.10	3.45	.059	.59	1.81	.30	.27	Trace	3.32	11.75
Beaver	56.29	63.39	2.20	.083	.22	1.93	.24	.17	.020	3.50	11.20
Biwabic	58.52	63.47	3.75	.039	.50	1.00	.27	.12	.004	3.35	7.80
Canton*	54.72	60.80	4.25	.048	.49	.93	.71	.07	Trace	7.31	10.00
Cincinnati*	......	61.08	8.00	.031	.75	.98	.34	.15	.015	......	9.00
Cincinnati Silica*	......	59.00	9 00	.030	.60	1.00	.34	......	.015	......	8.00
Climax*	......	63.64	1.94	.036	.87	.60	.88	Trace	Trace	......	8.65
Cloquet*	......	61.47	4.30	.046	.54	1.45	.35	.10	.019	......	17.37
Commodore*	58.14	64.10	3.90	.039	.20	1.21	.24	.06	.004	3.40	9.30
Duluth	54.11	60.94	5.10	.043	.36	1.48	.20	.16	.011	5.46	11.20
Etna*	......	64.00	3 50	.045	.50	1.85	.35	.15	.010	......	11.00
Fayal	56.92	63.09	3.38	.031	.91	1.09	.30	.24	Trace	3.68	9.78
Franklin*	......	63.15	3.78	.035	.50	.94	.14	.21	012	......	7.53
Genoa	57.18	63.49	4 05	.030	.48	.84	.40	.25	Trace	3.30	9.94
Hale*	......	60.00	5.00	.100	.55	.52	1.58	......	.016	......	9.00
Hartley	58.21	64.94	2.50	.037	.44	1.55	.45	.17	.004	2.77	10.36
Helmer*	......	64.00	3.65	.051	.48	1.80	.15	.10	.015	......	11.15
Hibbing	58.25	65.24	2.78	.028	.441	1.068	.08	.108	.011	2.34	10.71
Juniata	51.50	58.88	5.89	.068	.94	......	......	......	......	......	12.54
Linwood	57.19	63.44	3.90	.049	.64	1.45	.30	.19	.006	2.60	9.85
Mahoning	......	64.92	2.55	.049	.44	1.79	Trace	Trace	......	......	10.34
Mangan*	......	59.80	5.50	.034	.68	1.52	.32	.10	......	......	13.55
McKinley*	......	62.30	8.36	.026	.37	.93	.48	.23	.016	......	8.75
Minnewas*	......	65.50	2.23	.046	.48	1.12	.20	.18	.010	......	9.00
Mountain	56.07	63.95	4.01	.049	.35	......	......	......	......	......	12.32
Norman	......	61.98	3.84	.067	.72	2.20	.44	.16	.004	......	10.40
Oliver	54.46	61.95	4.76	.060	.54	......	......	......	......	......	12 09
Pillsbury	56.87	62.72	3.41	.023	.72	1.09	.09	.13	.001	3.86	9.33
Preble	52.87	58.91	5.34	.079	1.26	......	......	......	......	......	10.25
Penobscot	55.90	63.50	4.07	.032	.47	1.21	.19	.10	.011	......	11.96
Roberts*	......	60.00	11.02	.022	.66	.93	.09	.12	.009	......	8.71
Saxon*	......	64.29	3.75	.039	.56	·21	.12	.04	......	......	8.00
Sellers	58.23	64.39	3.49	.036	.39	1.35	.12	.05	.020	2.30	9.56
Shenango*	......	64.07	2.69	.060	.30	1 62	.20	.16	.020	......	10.53
Sparta	60.77	65.30	2.70	.029	.31	.74	.45	.23	Trace	2.35	6.94
Top Brown	58.14	63.45	3.29	.052	.52	.82	.50	.16	.004	3.94	8.36
Valley*	......	61.03	5.66	.041	.31	......	......	......	......	......	12.76
Vega*	......	61.99	5.40	.040	.26	1.45	.33	.18	......	......	11.57
Vulcan	......	64.60	3.06	.037	.50	.80	.35	.25	Trace	......	7.00
Williams*	......	60.40	9.20	.036	.77	.95	.42	.12	.011	......	9.70
Average	......	62.55	......	.040	......	......	......	......	......	......	......

*Expected analysis for 1899. All others are the average for 1898.

Vermilion range.

ORE	Iron, Natural State	DRIED AT 212° FAHRENHEIT.									Moist.
		Iron	Silica	Phos.	Mang.	Alumina	Lime	Magnesia	Sulph.	Org. and Vol.	
Chandler	60.98	64.72	4.02	.037	.11	1.94	.40	.11	Trace	.90	5.78
Long Lake	57.11	61.64	6.97	.042	.17	3.38	.37	.17	Trace	1.38	7.35
Minnesota	66.67	67.37	2.50	.055	.11	.69	.31	.11	.005	.26	1.04
Pilot	55.06	60.10	8.95	.044	.25	2.95	.21	.09	.024	1.34	8.38
Pioneer	59.80	64.48	4.33	.037	.202	2.123	.10	.072	None	1.24	7.26
Red Lake	61.66	63.32	4.58	.123	.14	1.70	.47	.46	.007	.75	2.62
Soudan	....	65.94	3.79	.10	.09	.96	.80	.55	.002	....	1.44
Vermilion	....	66.72	2.19	.137	.09	.90	.56	.25	.010	....	1.21
Zenith	....	65.03	3.82	.051	.16	1.88	.47	.15	.000	....	5.04
Average	....	64.36	....	.069	....	....	....	....	....	....	....

Comparative analyses of lake Superior and some foreign ores.

Messrs. Jeremiah and A. P. Head.

ORE	Iron	Silica	Phos.	Mang.	Alumina	Lime	Magnesia	Sulph.	Org. and Vol.	Moist.
Lake Superior.										
Marquette, average	59.44	9.72	.068	.403	1.76	.43	.39	.023	2.10	7.01
Menomonee, average	58.50	8.61	.144	.297	1.74	1.07	1.68	.047	2.57	6.98
Gogebic, average	60.60	6.79	.048	1.720	1.13	.21	.14	.014	2.36	10.66
Vermilion, average	64.73	4.52	.068	.210	1.60	.55	.20	.004	.55	4.53
Mesabi, average	62.64	4.33	.047	.550	1.28	.35	.15	.010	3.46	10.13
Spanish.										
Rubio (good)	56.50	7.50	.013	.713	1.22	.31	.10	.03	....	11.00
Campanile (good)	54.90	5.48	.009	1.010	1.13	3.55	.18	.03	....	11.00
British.										
Cumberland and Lanc. Hem.	57.60	10.52	.018	.324	3.06	....	.18	.01	....	8 00
Forest of Dean Hematites	59.15	2.52	.022	.070	.72	1.18	.65	.010	....	8.90
Swedish.										
Gellivara, grade A	69.51	1.90	.010	.072	.25	.202	.68	.038	....	.14
Gellivara, grade D	65.00	2.05	1.353	.108	.09	3.688	.92	.038	....	.14
Grangesberg	63.95	0.76	.760	....	....	....	....	.365	....	....
Indian.										
Kanjamalai	66.34	3.88	.043	nil	1.48	nil	nil	.22	....	....

METHODS OF EXPLOITATION.

Mining. The different conditions obtaining at our different iron mines have given rise to varying methods of operation. Improvements and economies have been constantly introduced in consequence of competition among producers and cheapened prices for ore, until, at present, the mining cost is much below what it has ever been, and many mines are today making records that a few years ago would have been deemed impossible. Thus, a few years ago (1890), the average cost of mining lake Superior iron ore was not far from $1.25 per ton. At present it cannot be much more than half that.

The mining methods which are in vogue on all but the Mesabi range are those which are necessary for underground mines; while on the latter range some of the largest mines are worked open to daylight (plate AAA, figure 2).

Owing to the irregular shape of the ore-bodies, no two mines are planned and worked exactly alike. It is customary, however, to sink one or more shafts in the foot-wall and connect them with the ore by cross-cuts at different levels. The amount of ore hoisted through one shaft depends, of course, on the depth of the mine, size of

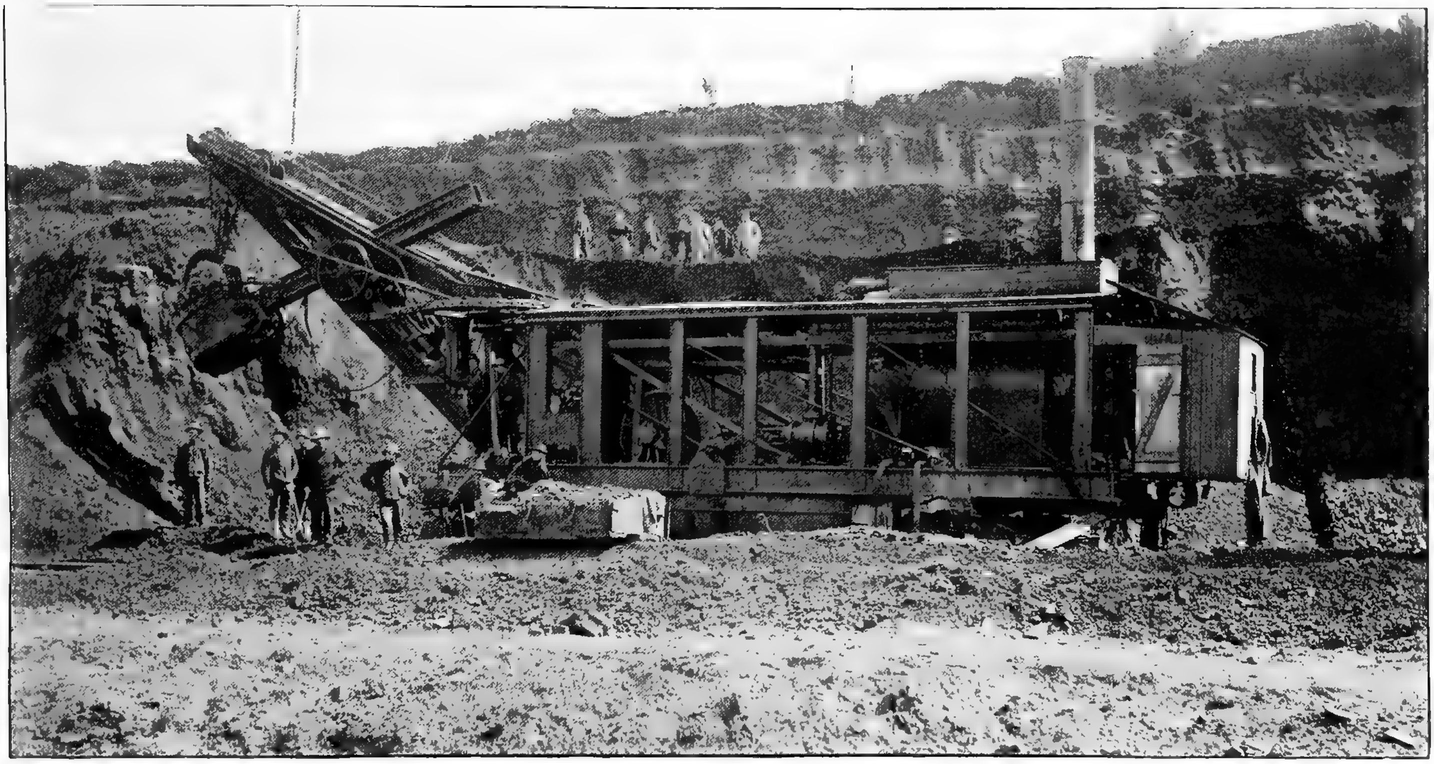


FIG. 1. STEAM SHOVEL AT MOUNTAIN IRON MINE. (p. 595.)

FIG. 2. LONE JACK AND MISSABE MOUNTAIN MINES, LOOKING WEST. (p. 588.)

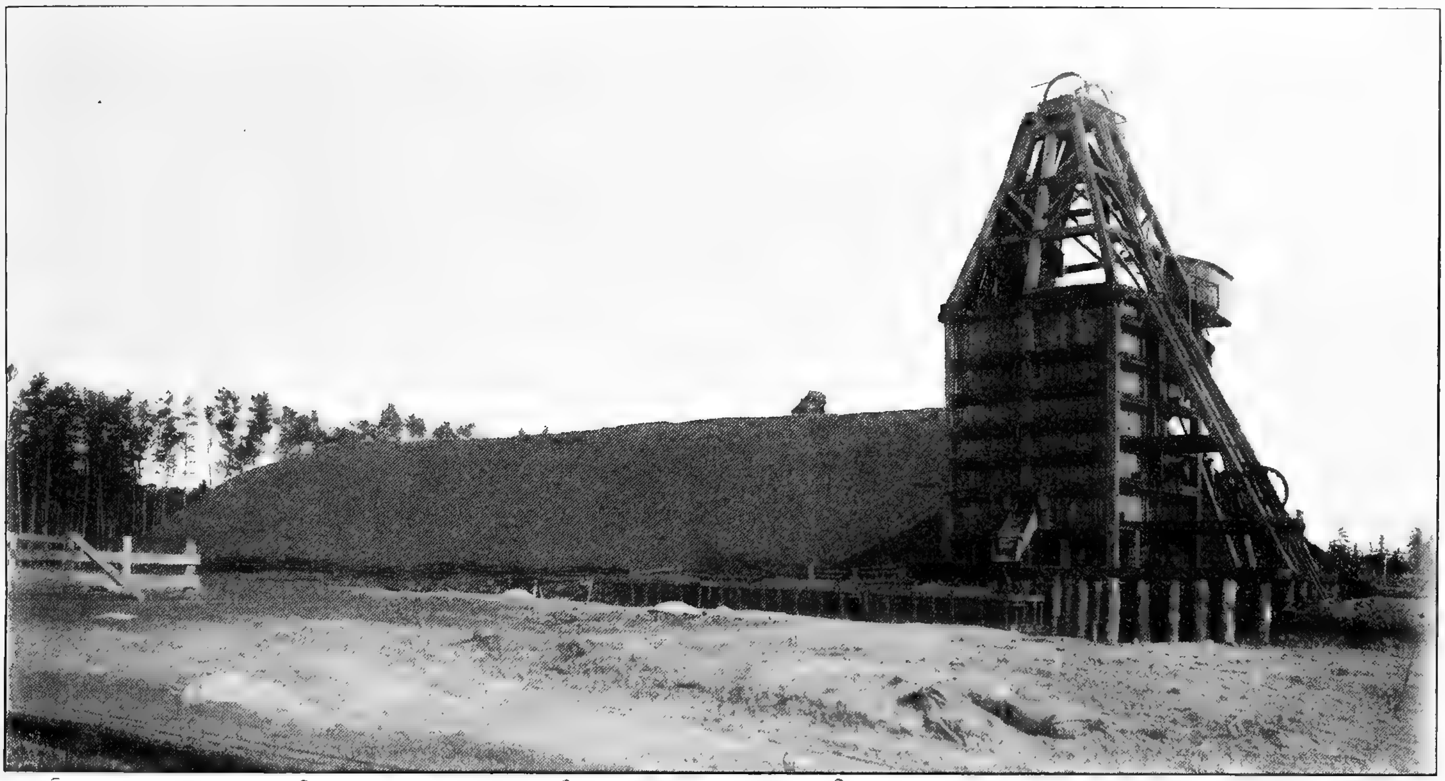


FIG. 1. BURT MINE NO. 1. SHAFT AND STOCK PILE. (p. 589.)

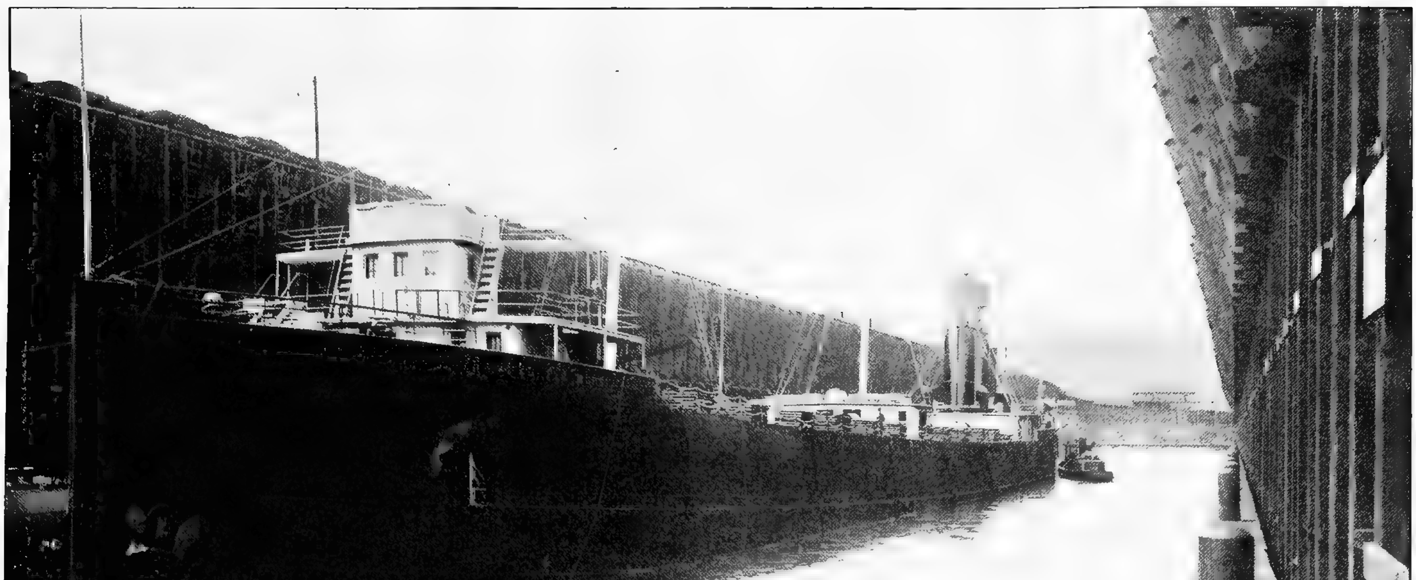


FIG. 2. ORE DOCKS OF THE DULUTH, MESABI AND NORTHERN RAILWAY, DULUTH. (p. 589.)

the shaft, size of the skips or cages, etc.; but it also varies much with the general plan of development and operation of the mine, and runs as high as 60,000 tons per month. The shafts have from one to four compartments, and are equipped with round iron wire hoisting cables, and with cages or skips of from three to ten tons capacity.

Much pumping is necessary at some of the mines and at others none at all.

Timbering varies in quantity and cost with the size and shape of the ore body and the methods of exploitation adopted. This item of cost, as well as that of powder for blasting, varies from nothing at some of the Mesabi mines to several cents per ton on the Vermilion range.

Tramming is done by hand and by mules, electricity not yet having been introduced in Minnesota mines. Hoisting and pumping are performed by steam and compressed air.

In an address read before the Engineer's Society of Western Pennsylvania, at Pittsburg, February 21, 1899, Dr. Nelson P. Hulst described in detail "Lake Superior methods of iron mining." From his interesting paper the following extracts are taken:

At Soudan. "The method of mining hard ore at the Soudan mine, on the Vermilion range, has been well worked out. I am indebted for the description here given, and for the drawings, to a paper by D. H. Bacon, the president and manager of the Minnesota Iron company. This was published in vol. xxi of the Transactions of the American Institute of Mining Engineers. The Soudan ore bodies have sometimes had a width ef eighty feet and varying lengths of several hundred feet. They lie as lenticular masses enclosed between locally-called greenstone rocks constituting the walls. They dip at a steep angle. Often they are friable and quite frequently treacherous. In the early mining the ore was quarried from open pits to the depth of 100 feet or more. For greater depth it became necessary to resort to underground mining. Shafts are located in the foot wall, as shown in figure 111. At intervals of seventy-five feet, cross-cuts are driven into and across the ore body, as shown on this figure. From each of these cross-cuts a chamber is mined out, twenty feet high, in the ore. These chambers to the several cross-cuts are shown in elevation in figure 111, and in plan in figure 112. Their longitudinal elevation is also shown in figure 114. The chamber of a level is made to extend on either side of the cross-cut as far as the character of the walls of greenstone or chloritic rock will permit. From the mouth of the cross-cut, where it opens into an excavated chamber, the timber work for a cross-cut is extended well into the excavated chamber. This timber work is well shown in elevation in figure 111, and in plan in figure 112. The timber work for longitudinal drifts is erected in these excavated chambers. As shown in plan in

figure 112 they extend from the timbered cross-cuts right and left. The timber work of raises is also erected alongside of the drift timbering just described. These are seen in plan in figure 112, and in elevation on seventh level in figure 111.

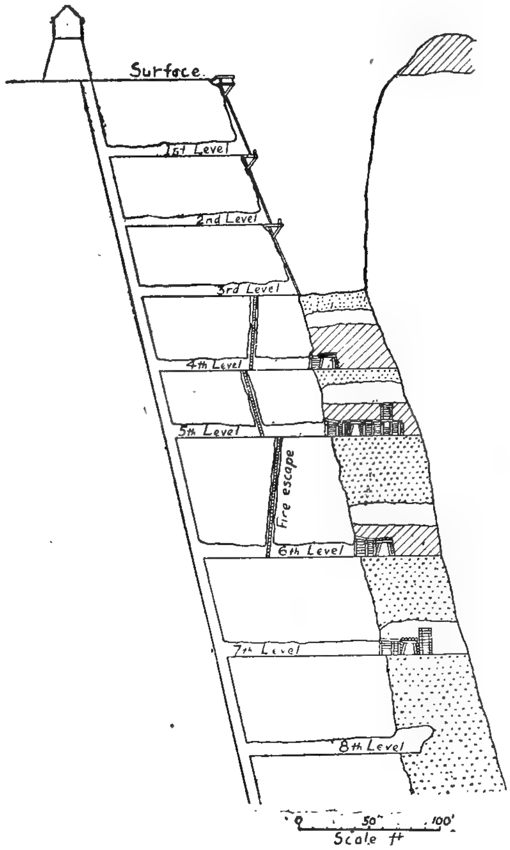


FIG. 111. CROSS SECTION OF SHAFT AND LEVELS AT NO. 8 SHAFT, SOUDAN.

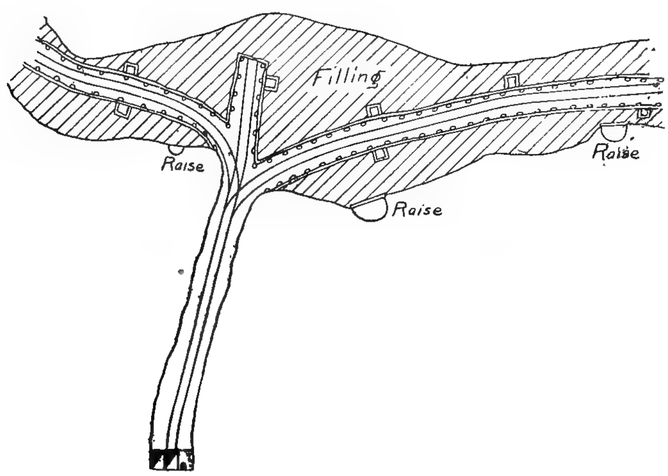


FIG. 112. PLAN OF THE FIFTH LEVEL AT NO. 8 SHAFT, SOUDAN.

"The timbered raises extend two to five feet above the timber work of the drifts they are connected with. Other timbered raises are erected for ladder ways. Still other raises are made to connect with the mine workings. These raises are in the

wall rocks, either foot or hanging, according to requirements. These raises in the wall rocks are used for rock chutes. Through them rock from the open pit, near the surface, is brought down to any level required. These rock chutes are seen in plan in figure 113, and in elevation in figure 112. After the timber work of cross-cuts, drifts and raises in an excavated chamber has been completed, then rock from the open pit above is run down through the rock chutes and filled around and over the timber work just mentioned, covering the drifts and cross-cuts to the depth of three or four feet. The excavated chamber is further extended right and left by stoping away twenty feet of ore above the level from wall to wall. The timber work of drifts is extended. The necessary timber work of raises for the lengthened drifts is completed. Stoping upward, *i. e.*, back stoping, is begun above the filling by blasting

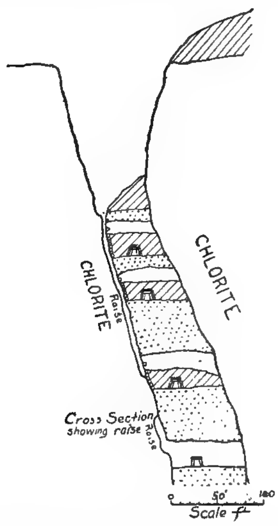


FIG. 113. ELEVATION SHOWING ROCK CHUTES.

down ten feet or more of ore from above and from wall to wall and as far as the filling over the timbering extends. This is shown in the longitudinal section in figure 114. The ore broken down on the filling is passed down to tram cars on the level below by the chutes described. After all this broken ore has been removed through the chutes, the chutes are built up to a proper hight and filling of rock is repeated as before. The stoping on the level is also repeated and timber work of drifts and raises erected in the extended chamber. Stoping, removing broken ore through the chutes, timbering and rock filling succeed one another until the level is nearly exhausted of ore. A roof of ore is of necessity left to support the rock filling of the level above. In the upper levels this roof of ore was successfully removed by back-stoping during winter, after the filling had become thoroughly frozen. At lower levels, where the frost could not well penetrate, this winter removal of ore could not be made. The roof was there left thick enough for drifts to be driven in it. It

was first caved down on the filling of the level below and then won by drifting and cross-cutting, which was not difficult in the broken ore."

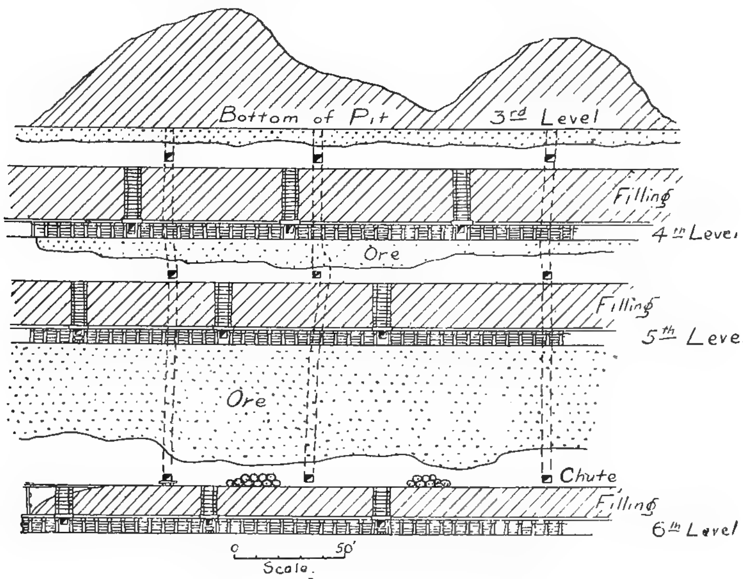


FIG. 114. LONGITUDINAL SECTION.

"*At the Chandler mine*, on the Vermilion range, a large product is annually obtained by a method of caving not largely differing from the others described. This mine being so prominent a producer and its ore a brecciated hard ore, makes it seem desirable that the method of mining by which its ore is won be accorded a description. The following description of the method used has been kindly furnished me by Mr. John Pengilly, the manager of the Chandler Iron Company:

"'The old system of mining has been abandoned from the eighth level down. Above the eighth level we opened the mine with seventy-five feet levels, with four intermediate or sub-levels between the main levels. The ore is dumped down the raises, converted into chutes, to the main level, where it is trammed direct to the shafts. The first sub-level above the main level is not opened until we are ready to cave, and in some instances is not opened then, if the ground shows an unusual amount of weight. To avoid a large opening, our experience so far has taught us to keep our caves as full as possible at all times, and to draw the capping as soon as possible after the ore. If the capping hangs, and does not come at once, there have been times when we have withdrawn our men for safety, until such time as the capping does come. This occurs only at the extreme east of the property, where we have always had the capping to contend with.

"'Our eighth level and above was originally opened, leaving large pillars. Raises for chutes were put up about every fifty feet to shorten the wheeling distance of the ore into them. It had also been found necessary to put up raises for ladder-ways to the sub-levels, so that in case of accident we can at all times withdraw our men.

The ladder-ways are not put up by any rule, but as occasion requires. The main levels are opened with a nine-foot cap and seven-foot posts, giving in a level seven feet by seven feet in the clear. Our sub-levels are opened with six-foot timber, tunnel-shape. Three pieces constitute a set. Our raises are mostly three feet square in the clear. This size we consider easier to maintain from crushing, and at the same time it can be guarded to better advantage than a large chute or raise.

"'When caving we run into or slice a pillar, and put up convenient raises or chutes for milling down the ore. Usually we commence to cave on the south and east of the deposit, working the caving back in a northeasterly direction, passing or caving such chutes or ladder-ways as we come in contact with. Our ladder-ways are put up on an angle of 65° to 75°. In caving, although we are governed in cases by circumstances and the character of the ore, we always commence at the loose end and draw at all times to the foot wall or dike. Timber for sub-levels is thrown down raises from the main level above and distributed from those points. Our tramming is done principally with mules to the main shafts. At the shafts are stationed a cage tender and an assistant to take the cars off and on the cage. In the station we have a system of tracks for loads and empties giving ample room to hold a full train of two or three cars as brought in by the mule, which returns with as many empties. This work is done with a boy and a mule.

"'We have also found it to our advantage to keep our tracks well graded and well drained by ditches cut at the sides of the drifts. Thirty pound rails are used for tracks. This part of our business we consider very important, as it avoids delays and accidents. The mule distributes empties to the several switches where chutes are being used in the sub-level. These empties are filled by the trammers at the chutes, caves or drifts, and then replaced on their switches, whence the mule hauls them to the shaft. In this way we avoid tiring our men by walking or pushing cars for any considerable distance. We try to cut down our grade as near as possible to one foot to 100 feet where tramming is done. Six inches to 100 feet is sufficient grade and will be established by us in the future.

"'Our hoisting is done on the vertical by cage and on the incline by skips; by high pressure engines and without balance. We have at times three to four levels to hoist from. Mules handle our ore on the surface. The ore on reaching the surface dumps automatically from the skip into a car to which a mule is attached, or if a cage the mule is hitched directly to the mine car. These cars are trammed or hauled to the stock pile. Empty cars, in both cases, follow the full ones into the places they formerly occupied. This is done by means of a system of tracks running through and beyond the shaft house, doing away with the turn table and the transfer car or truck. A load for a mule on the stock pile is two to three two-ton cars. In

the mine we endeavor to concentrate our men; working them in a certain section and giving a foreman charge of each gang of men, to see that they do a fair day's work, and at the same time to protect them from danger. There are not more than ten per cent of our men who speak the English language, and not more than the above number who have the remotest idea of mining. We do not allow any foreman to have charge of more than twenty-five men.

"'All ore mined on the seventh level, as above, is dumped down the old No. 4 shaft, which is used for that purpose as a pocket. It is taken out on the eighth level and trammed to No.5 shaft, 300 feet distant to the north. All ore below the eighth level is also dumped down No. 4 shaft or pocket to the thirteenth level, 110 feet below the eighth level, and taken to No. 5 shaft and hoisted. No. 4 pocket has three compartments, for first and second grade ore and for rock. Our No. 2 and No. 3 shafts hoist from the seventh and eighth levels and will eventually hoist from the thirteenth.

"'Below the eighth level we open what is termed in this mine "main sub-levels," twenty-two feet from bottom to bottom. These levels are known as the ninth, tenth, eleventh and twelfth main sub-levels. The drifts are opened directly under the main eighth level drifts. The thirteenth level is opened somewhat differently, owing to the pith of the ore body. In opening up our main tramming level, we have rock drifts of considerable length from the ore body to each shaft.

"'To No. 5 shaft, 310 feet; to No. 3 shaft, 250 feet; to No. 2 shaft, 265 feet. These rock drifts are usually timbered and will measure at least ten feet in clear, or inside the timber. In mining our ore, we encounter much rock and clay in the form of horses, seams and bunches. This necessitates careful mining and much rock picking to keep the ore up to grade. On a basis of 600,000 tons of ore mined, we hoist about 18,000 tons of rock, two-thirds of which actually comes from the ore body and one-third from the rock drifts, shafts, raises, etc.

"'*Milling system on the Mesabi range.* There has been introduced in the Mesabi range a method of mining called the "milling system." Many of the Mesabi ore bodies lie at no great depth from the surface, and a very flat dip is characteristic of all of them. When the depth of the overburden of sand and gravel is not great, and the conditions do not warrant the removal of the ore by steam shovels, the so-called milling system is very successfully used. This method involves at the first an entire removal of the overburden of sand and gravel, leaving the uncovered surface of ore very clean. A shaft or shafts are sunk in the adjoining rock, and cross-cuts and drifts in the ore are driven, which connect with the shafts. Up-raises are made at numerous points from the cross-cuts and drifts. These are properly timbered to serve for ore chutes, with the necessary spouts for loading the ore therefrom into tram cars on the levels or cross-cuts. When the preparations for mining ore

are completed, the ore about the up-raises is blasted into them. It is drawn from them into the cars stationed in the levels as rapidly as the facilities for handling the ore to the surface permit. The ore being very soft, up-raises are made at slight expense. The raises, closely spaced in the ore body, enable the winning of ore to be accomplished at a minimum of expense. It is evident that there is no lifting of the ore whatever by manual labor. In the blasting, much ore is tumbled directly into the chutes, and the unskilled laborers drag or push the ore down the slopes and into the chutes by their shovels with a minimum of effort. By this method of mining, the product of ore per day per man is very great. The waste of ore in this method of mining is practically nothing.

"'A large tonnage of the Mesabi ores is annually produced by steam-shovel mining. About fifty per cent of the Mesabi range product in 1898 was thus produced. This method of mining requires that the overburden of gravel and sand be removed so as to leave the uncovered surface of the ore body practically clean. A bank or bench of ore twenty feet high is found generally most advantageous. A higher bench will often give trouble by caving on the steam shovel at the time of blasting. Although the Mesabi ores are soft, yet, as they lie undisturbed in the bed, they are too coherent to be shoveled without being blasted. In some of the mines there are hard strata, against which a steam shovel is not economically effective. The holes for blasting the ore are drilled by hand. Drawing the drills consumes much time. They are usually fifteen to sixteen feet apart and nine feet from the edge of the bench. They are driven fifteen feet deep. Steel drills one and one-eighth inches in diameter are used. Men drill three holes per day at the Mountain Iron mine. For cracking the holes at the bottom to make a cavity for a charge of black powder, three one-pound sticks of forty per cent giant powder are used. Steam shovel mining, to be economical, requires that there be no delays in the work. Large tonnage is possible when conditions are all favorable. Two hundred and thirty-two cars, containing 5,825 [gross] tons, have been loaded at the Mountain Iron mine in nine and a quarter hours by a ninety-ton Vulcan shovel. The best record for one hour has been thirty-two cars, or 800 tons'" (plate AAA, figures 1 and 2).

Crushing. The hard hematite ore of the mines at Soudan comes out of the ground in masses too large to be handled easily in shipping or charging at the furnaces. Formerly the large blocks were broken by hand, and a man with a twenty-pound sledge hammer would pound for hours, exerting his whole force, before reducing a particularly hard and tough lump to convenient size.

The installation of large crushers has greatly reduced the labor and expense of breaking this ore into small lumps. The following description of these crushers is taken from a paper by F. W. Denton:*

* *Trans. Am. Inst. Min. Eng.*, xxvii, p. 350, 1897.

DATA CONCERNING CRUSHERS.

"There are two crusher plants, of identical size and arrangements. Each plant contains three twenty-eight by thirty inch crushers of the Blake pattern.

Throw of eccentric,	2 inches
Movement of bottom of jaw,	1¼ inches
Weight of pitman,	5 tons
Weight of jaw,	7 tons
Weight of crusher,	65 to 70 tons
Speed of crusher,	85 revolutions per minute

"Each plant is driven by a Reynolds-Corliss engine and rope-drive as follows:

Cylinder,	14 inch diam. by 36 inch stroke
Speed,	90 revolutions per minute
Initial steam pressure,	95 pounds
Diam. of fly-wheel,	10 feet
Weight of fly-wheel,	8 and 10 tons
Distance between centres of engine-shaft and counter-shaft for rope-drive,	75 feet
Diam. of manilla ropes,	1½ inches
Number of ropes,	6
Number usually in use,	4

"In a communication to the Lake Superior Mining Institute the cost of crushing is given as follows: †

"'During three months ending January 1, last (1896), 110,477 tons of ore passed through the crushers, costing for supplies $5,025, or 4.54 cents per ton, and, grouping the other accounts, $3,718.47, or 3.36 cents per ton; total, $8,743.47, or 7.9 cents per ton. We have no means of determining what percentage of the ore needs to be crushed, but assuming it to be sixty per cent, the cost was 13.19 cents per ton.'"

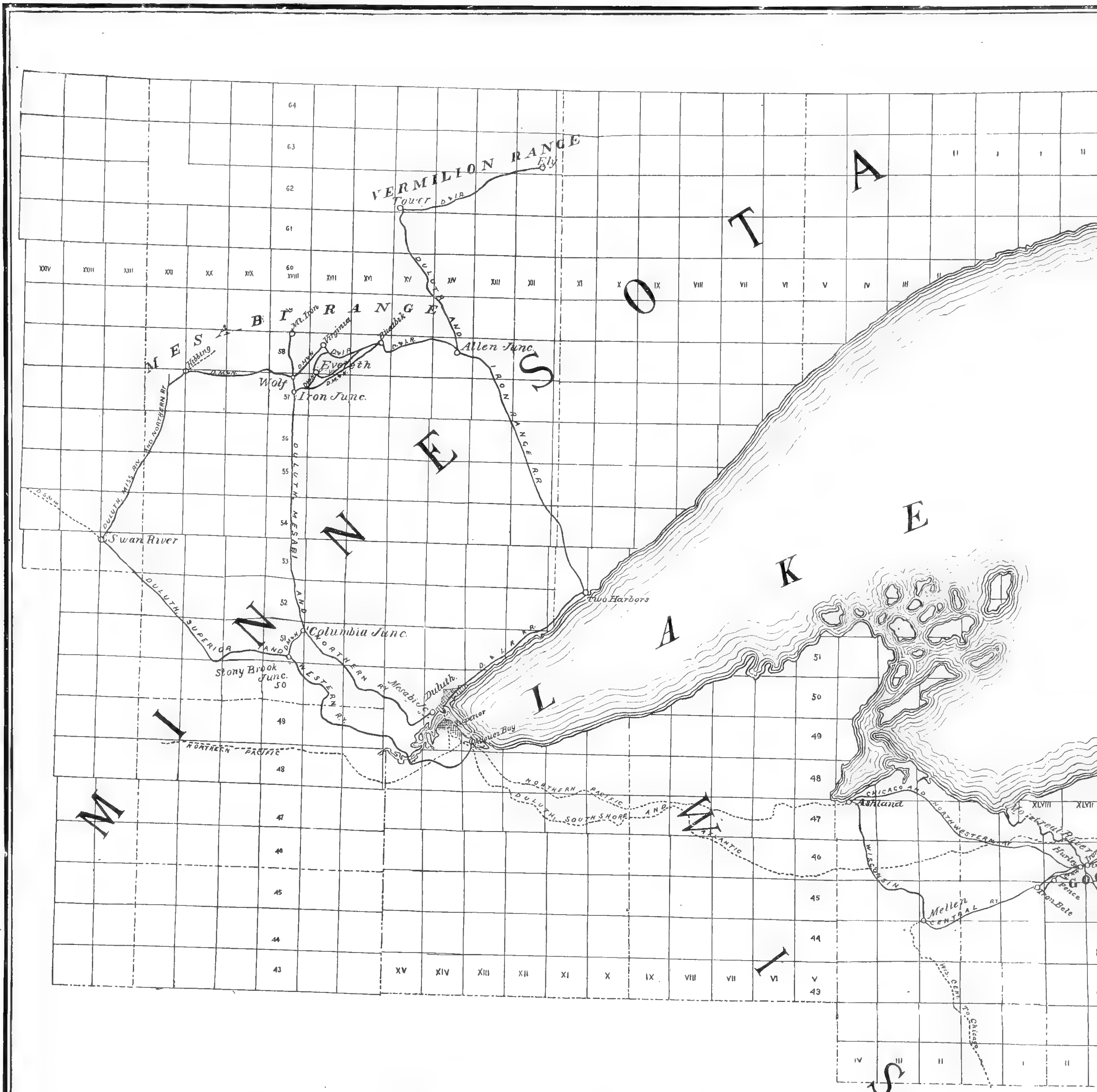
The ore handled in these crushers is so hard and tough that only specially hard manganese steel is able to stand the wear. This is so hard that no tool is equal to the task of dressing or in any way making an impression upon it.

Transportation. Three railroads are now in operation between the iron mines and the docks on lake Superior. They are all standard gauge and equipped with first-class rolling stock. The first to be constructed and the easternmost of these roads is the Duluth and Iron Range. It belongs to the Federal Steel company which now controls the Minnesota Iron company and carries about half the ore shipped from Minnesota mines. It runs to Tower and Ely on the Vermilion range, and is extended to the mines of the Mesabi range as far west as Virginia. Its docks are at Two Harbors, twenty-three miles east of Duluth.

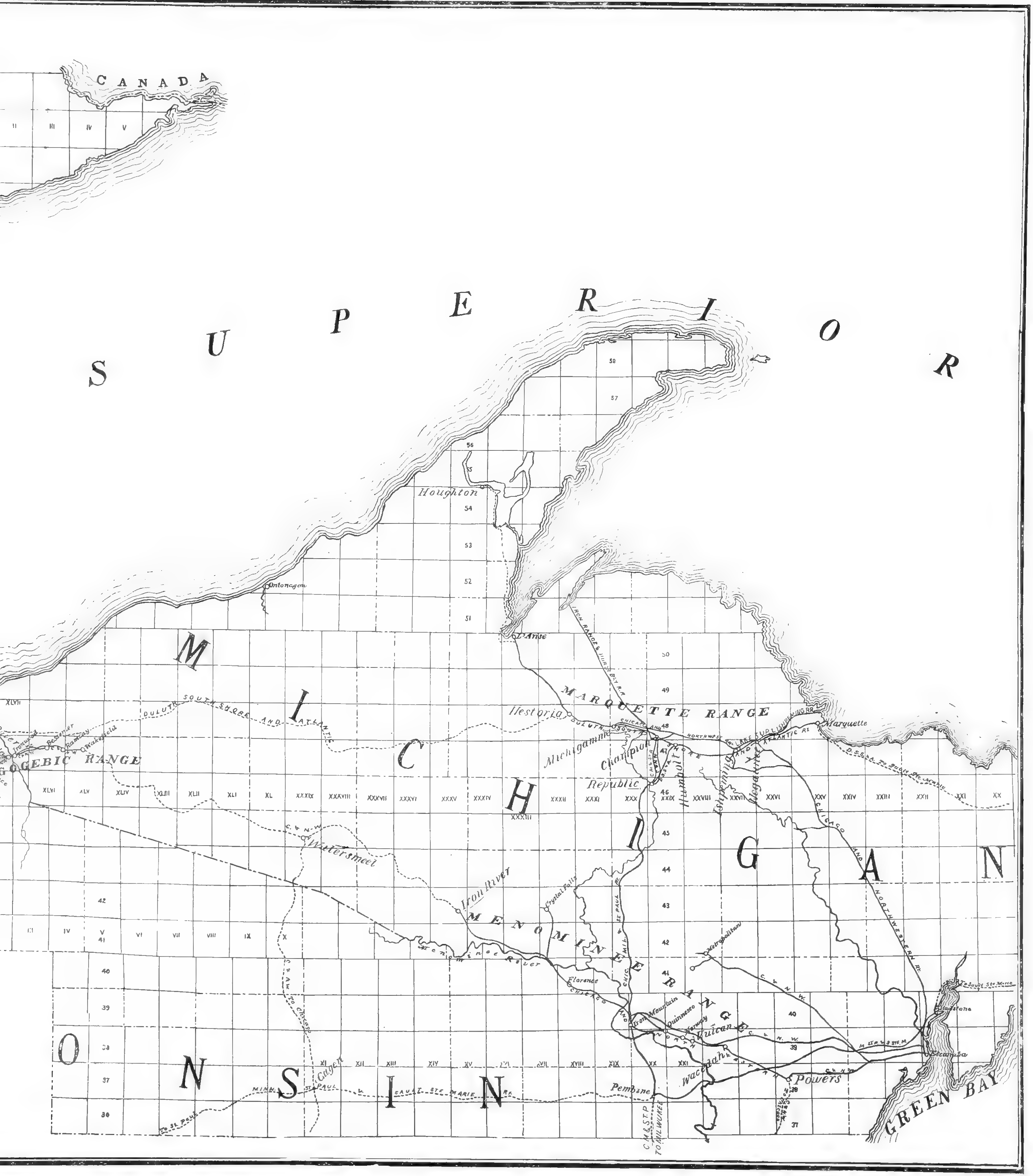
The Duluth, Mesabi and Northern railroad has docks at West Duluth. This road is owned by the Lake Superior Consolidated Iron Mining company, and serves Mesabi Range mines alone.

The Eastern Minnesota railway has also a line running to the western end of the Mesabi range, and is now constructing an extension from Hibbing to Virginia.

† *Proceedings*, iii, 1896.



MAP
SHOWING LOCATION OF THE
LAKE SUPERIOR IRON RANGES
AND THEIR RELATION TO SHIPPING POINTS.


CANADA
SUPERIOR
MICHIGAN
ONSIN
Houghton
Ontonagon
L'Anse
MARQUETTE RANGE
Marquette
Ishpeming
Negaunee
Michigamme
Champion
Republic
Humboldt
GOGEBIC RANGE
Wakefield
Bessemer
Ramsay
Watersmeet
Iron River
Crystal Falls
MENOMINEE RANGE
Menominee River
Florence
Iron Mountain
Quinnesec
Norway
Vulcan
Waucedah
Powers
Pembine
Metropolitan
Escanaba
Gladstone
GREEN BAY
Cagen
DULUTH SOUTH SHORE AND ATLANTIC
CHICAGO AND NORTHWESTERN RY.
MINN. ST. PAUL & SAULT STE. MARIE RR.
To St. Paul
To Sault Ste. Marie
C. M. & ST. P. TO MILWAUKEE
IRON RANGE & HURON BAY R.R.

It is understood that this line has concluded traffic arrangements with the American Steel and Wire company, and will haul the ore from its mines as well as that from the Mahoning mine.

The map appended will show the position of the different iron ore railroads of the lake Superior region (plate CCC).

The iron ore from the different lake Superior mines is carried by rail and water to ports on lakes Michigan and Erie, chiefly the latter, and there unloaded into railroad cars for further transport to the furnaces in Ohio and Pennsylvania, or piled up on receiving docks and stored until sold during the winter or early spring. None of this ore is at present smelted in Minnesota, and but a nominal amount in Wisconsin and Michigan, owing to the entire absence of deposits of suitable coal. Charcoal iron to the amount of about 200,000 tons per annum represents the total pig iron product of states which annually produce 10,000,000 gross tons of iron ore.

The distances traversed and the railroad rates charged per gross ton (2,240 pounds) from mines to upper lake ports are as follows:

	Rate.
From Marquette range east of Republic and Michigamme to Escanaba, distance not over sixty-five miles,	$0.52
From Marquette range at Republic and Michigamme to Escanaba, distance — miles,	0.67
From Marquette range to Marquette, fifteen miles	0.32
From Marquette-range to Gladstone, 60 to 130 miles,	0.52
From Menominee range east of Mastodon to Escanaba, maximum distance fifty-two miles,	0.40
From Menominee range west of Mastodon (Crystal Falls), distance eighty-two miles,	0.43
From Gogebic range to Ashland, distance about forty-five miles,	0.40
From Gogebic range to Escanaba, distance about 184 miles	0.85
From Vermilion range to Two Harbors, distance sixty-eight to ninety miles,	1.00
From Mesabi range to Duluth and Superior, about seventy-five miles,	0.80

The sailing distances and average ton rates for ten years (1886 to 1895) are as follows:

	Miles.	Contract Rate.	Wild Rate.
Marquette to Cleveland,	583	$1.09	$1.12
Escanaba to Cleveland,	523	0.91	0.915
Duluth to Cleveland,	823	1.19	1.30
Ashland to Cleveland,	774	1.19	1.30
Escanaba to Chicago,	192	....	....

The average contract rates for the seasons of 1895 and 1896 were:

	1895.	1896.
Escanaba to lake Erie ports,	$0.55	$0.70
Marquette to lake Erie ports,	0.75	0.95
Ashland and Duluth to lake Erie ports,	0.80	1.05

From this statement it may be seen that there has been a great reduction in vessel charges in recent years. In spite of this fact, however, the cost of transportation is to-day a larger part of the cost of the ore in Cleveland than it has ever been.

This freight and a great deal more all passes through the canal and locks at Sault Ste. Marie, one of the busiest spots on the globe during the season of navigation. During the year 1895 the tonnage passed through the Manchester ship canal was but one-tenth of that which passed through the "Soo." During the year 1895, naviga-

tion was open from April 25 to December 11, and in this time 17,956 vessels passed these locks, the registered tonnage of which aggregated 16,806,781 tons, and the value of whose freight was $159,575,129. There are at present 3,300 vessels (1,755 steam) on the great lakes, with a total registered tonage of 1,250,000 tons. Many of these vessels are of 4,000 tons burden, and exceed 400 feet in length. The loads which they carry vary from 4,000 or 4,400 gross tons on a draught of fourteen or fifteen feet to 6,000 tons on a twenty feet draught.

The speed with which these vessels are loaded and unloaded is one of the marvels of the day. The record of the steamer "Victory" may be mentioned in this connection.* It is a vessel 400 feet long and of forty-eight feet beam, with a carrying capacity on fifteen feet draught of 4,000 tons. It was loaded with coal at lake Erie port in ten hours. At Superior this coal was discharged in fifteen hours, and a new cargo of iron ore taken on in five hours, at the rate of 800 tons per hour. Arrived at a lower lake port this ore was unloaded onto cars at the rate of 560 tons per hour. (Compare plate BBB, figure 2.)

On lakes Superior and Michigan there are to-day twenty shipping docks: four at Escanaba, three at Ashland, five at Two Harbors, two at Duluth, four at Marquette, one at Superior and one at Gladstone, with 4,529 pockets of an aggregate capacity of 672,966 gross tons. When the pockets of the loading docks are filled with the ore desired, it is not an uncommon occurrence for a vessel to tie up, load and depart within two hours. One record has been made of 2,350 tons of ore loaded in three-quarters of an hour. The capacity of ore-carrying vessels has recently been largely increased, as is related in the following extract from the Bulletin of the American Iron and Steel Association:†

Never before in the history of American shipbuilding has such work been seen as has been done in the construction of the Bessemer Steamship company's fleet of lake-freight ships. About the close of the first week in December last the company was formed, and its Cleveland agents made contracts with lake ship-yards, all then fairly full of work, for the building of twelve great ships, each to be larger than anything on the lakes, with the exception of one steamer afloat and two under contract for the Zenith Transportation company of this city. The end of this week sees seven of these ships in commission, while one more will be set at work about September 20th, and the remaining four will be ready in October. In addition four ships have been purchased and the fleet as it will be before the close of the coming month—less than ten months after the decision to build was made—will have a capacity for carrying the enormous quantity of 65,000 tons on present and 95,000 tons on the coming deeper draught. These ships have cost about $3,400,000.

The Bessemer Steamship company was the outgrowth of the control by Mr. John D. Rockefeller of the mines formerly under the Merritt ownership on the Mesabi range and of the railway between those mines and Duluth. Mr. Rockefeller reasoned that, owning both the mines and the railway to the water, he should control as well the transportation of the ore to the lower lakes. To decide was to act, and one of the most important fleets in American waters, salt or fresh, was completed in less than a year. It was proposed that this fleet should be able to handle the output of the mines, and as planned they will be able to carry about 2,000,000 tons in one season.

The contracts for the Bessemer fleet filled all the lake yards with tonnage till about the middle of the spring, when the boats began to slip into the water. Since then, there have been no contracts made, and with the completion of the last of these ships nine great shipyards along the lakes will be idle, with no business in sight. This is a condition that has not prevailed for many years, for even in the panic of 1893 there was business for some of the yards. Many thousands of men will then be out of work.

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*Mr. John Birkinbine. *Cassier's Magazine*, April, 1897, p. 494.

†October 1, 1896.

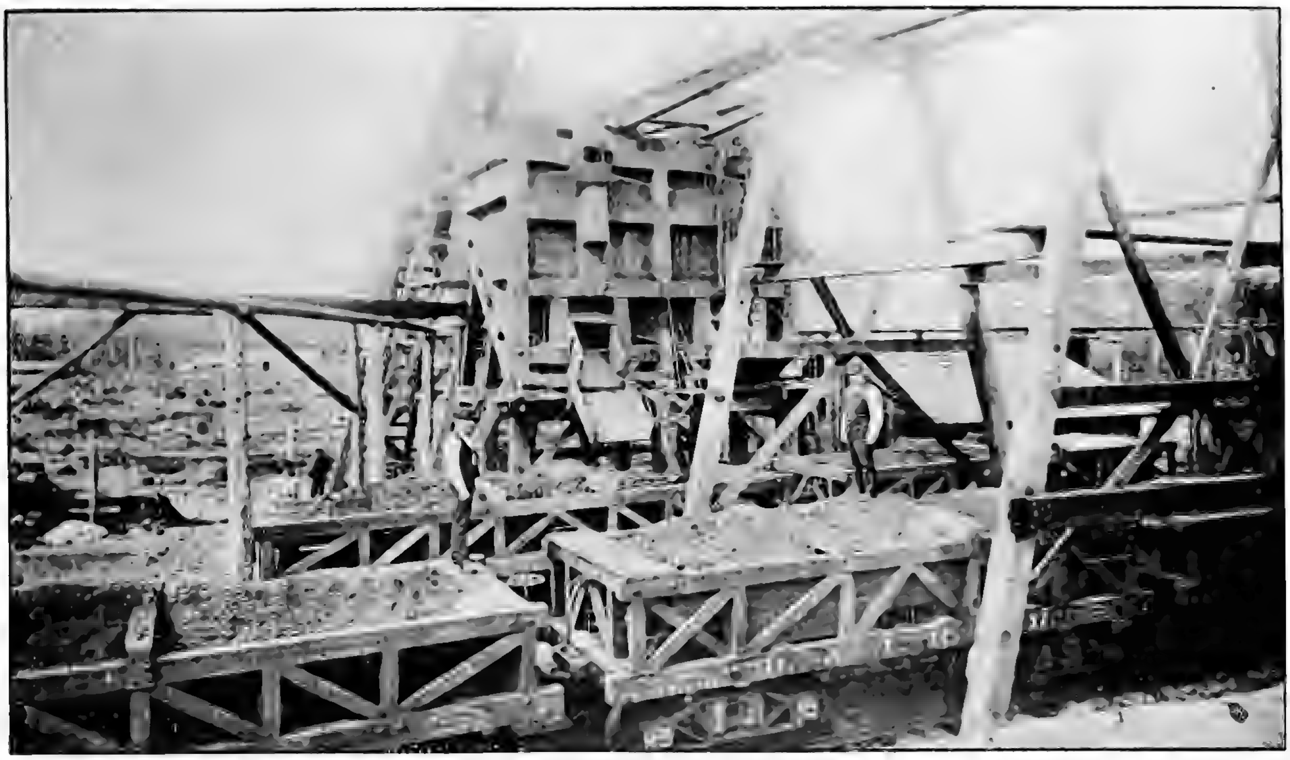

FIG. 1. LOADING AT THE CHANDLER MINE. (p. [illegible])

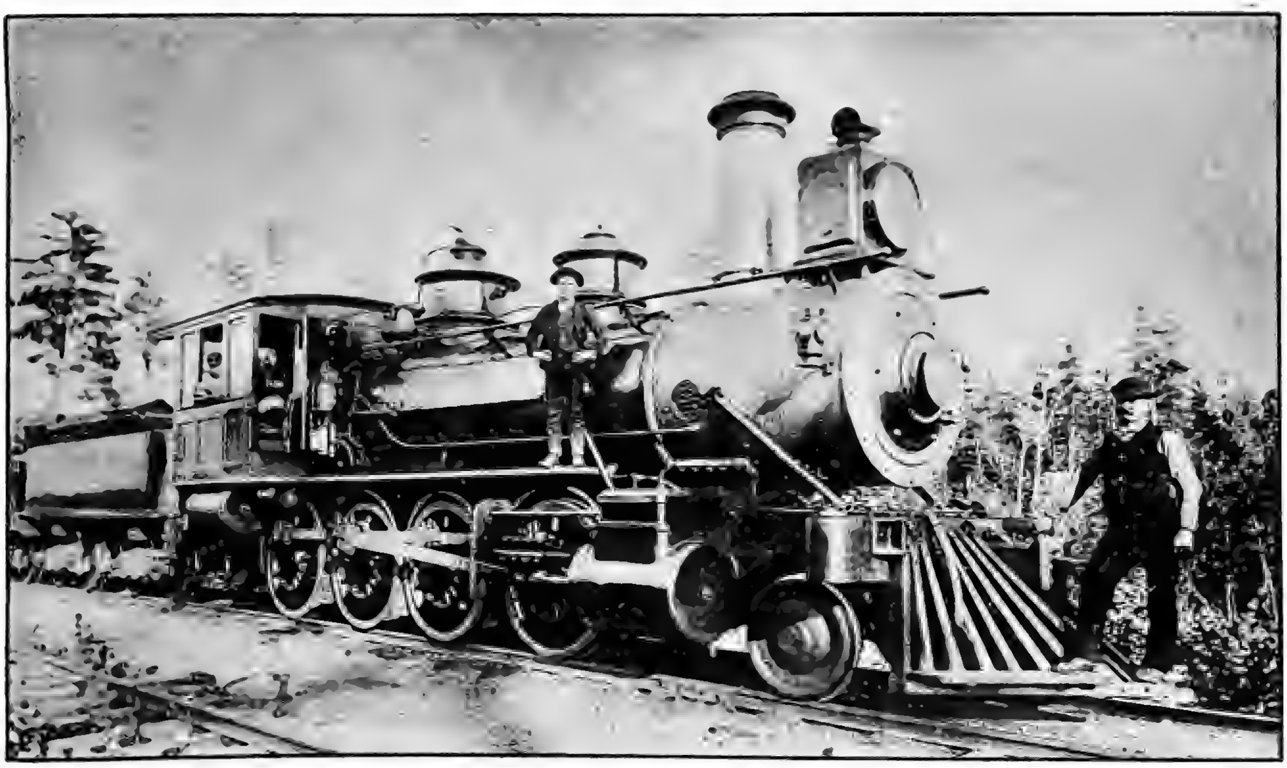

FIG. 2. THE LOCOMOTIVE OF THE ORE TRAINS. (p. 599.)

The vessels of the Bessemer fleet have been appropriately named for men famous for their connection with the mining, engineering, and metallurgical world. The flagship of the fleet is the "Sir Henry Bessemer," while among the others are such names as "Nasmyth," from the inventor of the steam hammer; "Ericsson," from the builder of the "Monitor"; "Corliss," the maker of engines; "Krupp," "Fulton," "Watts," "Siemens," "Bell," "Fairbairn," and "Holley." Amid all the development of the lake marine and steel interests in the last few years it has strangely enough remained for this new company to honour the memories of the greatest men these industries have had by naming ships for them. The "Bessemer," "Siemens," "Fairbairn," and "Ericsson," and the barge "Holley," are now in commission, and each one has carried loads enough to test its capacity. They were all built on a guarantee by the constructors of a capacity, on fourteen feet draught, of 4,000 gross, or 4,480 net, tons. Each has slightly exceeded these figures. Were these vessels operated on the draught of water for which they were built they would be able to carry between 6,500 and 7,000 tons each, and they will be able to use nearly this depth of water by the beginning of another season, when the government's twenty-one feet channel between Duluth, Chicago and Buffalo will have been completed.

The cost of unloading ore from the vessels has been much reduced in late years by the construction of unloading devices which take the ore after it is loaded into buckets and automatically carry it to the stockpile, dump it and return it for a new load. This cost is now but one or one and a half cents per ton.

The railroad equipment of the ore-carrying roads compares in size and efficiency with that employed in marine traffic. The roads are standard gauge, the rails are heavy and of large section, weighing eighty or ninety pounds to the lineal yard; the locomotives are among the most powerful ever built, weighing from 80 to 120 tons, and hauling trains of from thirty to fifty cars, carrying 750 to 1,250 gross tons of ore at an average speed of seventeen miles per hour, including stops. Some of the roads are double-tracked and others will be soon.

The amount of capital invested in lake Superior iron mining has been estimated as follows by Mr. George H. Ely and the Lake Carriers' Association of Cleveland, Ohio. These data were compiled as largely as possible from official sources and were presented in a statement to congress:

Capital in the mines of the four iron-ore ranges, as shown by United States census and estimates since last census was taken,	$96,325,122
Capital in docks and their equipment at lake Superior and lake Michigan ports, built and used exclusively for shipping ore (official),	14,185,665
Capital employed exclusively in railroad transportation of ore, from mines to shipping ports on lakes Superior and Michigan (official),	32,364,594
Floating capital on the lakes, employed exclusively in ore transportation from Upper lake to Lower lake ports, estimated,	46,680,207
Capital in docks and in their equipments for receiving and forwarding ore exclusively, at lake Erie ports between Toledo and Buffalo, inclusive of both (official)	15,492,880
Capital employed exclusively in rail transportation of ore, inland to mills and furnaces from lake Erie ports (official),	28,193,617
Total, January 1, 1896,	$233,242,085

The amount invested during the year which has passed since the preparation of the above table has witnessed the construction of the large fleet of vessels owned by Mr. Rockefeller, the new iron ore railroad in Pennsylvania, owned by the Carnegie company, the railroad between Ishpeming and Marquette, and improvements and extensions of docks and railroad and mine equipments in all directions, so that it is probably not an exaggerated estimate to place the amount of capital invested in lake Superior iron mining at $250,000,000.

MARKET PRICES OF IRON ORES.

One after another of the great lake Superior iron ore ranges has been discovered and developed, and as methods of mining and handling the ore have improved in efficiency and detail, prices have reached lower and lower levels; the margin between cost of production and selling price has constantly narrowed, and earnings have been made on larger outputs and greater economy of operation. The discovery of the immense Mesabi deposits of soft ore so much more cheaply mined than the hard ores has, however, had a much greater effect on prices of iron ore and of iron and steel than any of the former discoveries. When prices were high and less ore was used very little account was taken of its exact composition and value. If a furnace ran well on a certain ore, the managers of that plant would purchase that ore year after year, even though they could get some other ore equally as good at a somewhat lower price. As competition among ore producers became fiercer, however, and furnace operators found it necessary to economize in their costs, the relative values of the different ores have been more and more closely scrutinized and made the basis of market prices until they have reached the point where quotations are in fractions of one cent per ton, and the older ranges have all combined against the prolific Mesabi range, forcing prices down to so low a rate that very few producers on any of the ranges can make any profits.

The prices have ranged somewhat as follows in former years:

Bessemer ore.

Year.	Price.
1856	$ 8.00
1866	9.50
1868	9.75
1873	12.00
1876	6.75
1881	9.00
1886	5.50
1887	7.25
1888	5.50
1889	5.50
1890	6.75
1891	6.00
1892	5.50
1893	4.00 to 4.50
1894	2.50 to 2.75
1895	2.75 to 3.50

Non-Bessemer ore.

1890	5.75
1891	4.75
1892	4.25
1893	3.00 to 3.50
1894	1.80 to 2.20
1895	1.90 to 2.20

These prices are for the ore delivered at Cleveland or any designated lower lake port. The ore is sold on guarantee as to quality, and is sampled and analyzed at the mines and at the receiving docks. A few illustrations of the way prices have ruled

on some representative ores during the past three years, including the prices established for 1897, are as follows:

Ore.	1895.	1896.	1897.	1898.
Aurora,	$3.00	$4.15	$2.80	$2.95
Biwabik,	2.65	3.65	2.50	....
Chandler,	3.05	4.25	2.925	3.13
Chapin,	2.55	3.65	2.40	2.56
Fayal,	2.25	....	2.40	....
Franklin,	2.75	3.75	2.55	....
Lake Angeline,	3.55	4.90	3.46	3.64
Minnesota,	3.40	4.55	3.11	3.36
Non-Bessemer,	....	2.65	2.25	....
Norrie,	2.90	4.00	2.65	2.84
Pewabic,	3.55	4.90	3.40	....
Pioneer,	3.05	4.25	2.87	3.03
Republic,	3.30	4.55	3.17	3.35
Tilden,	2.90	4.00	2.56	

During 1896 prices were maintained at a high level through the agency of an ore pool or general agreement among the principal producers. It was found impossible to make satisfactory allotments to all parties for 1897, however, owing to dissatisfaction with the operation of the arrangement in the previous year, and the only agreement which now exists is one among the producers of the three Michigan and the Vermilion ranges.

Vermilion Range mines. As already mentioned, the mines of the Vermilion range, so far as developed, are in two groups, one at Ely and the other at Soudan. The best known of the Ely group is the Chandler mine. This mine has produced nearly 5,000,000 gross tons of hematite ore up to the season of 1899, an average of nearly half a million tons per annum since it was first opened. Its output is controlled by the Federal Steel company. The grade and physical character of this ore make it one of the most desirable produced in the Lake Superior region. Its product is remarkably uniform in every respect, and as the ore occurs crushed in its natural state it is mined and handled easily and cheaply. It has been a source of great profit to both fee owners and lessees. In another place will be found an account of the methods employed in mining this ore.

Other mines at Ely are the Pioneer and Zenith, operated by the Oliver and Carnegie interests, under lease from private fee owners. The Pioneer lies just east of the Chandler, and is part of the same ore deposit, lying at greater depth, underneath a jasper capping. The Zenith lies still farther east in the same belt, and the Savoy, a new property, lies east of the Zenith. The Pioneer ore is similar to the Chandler, but the Zenith is of slightly lower grade.

At Soudan the mines are all owned by the Minnesota Iron company, now part of the Federal Steel company. These deposits have yielded something over 6,000,000 gross tons of hard hematite, the first year of production having been 1884. The ore here varies in quality, and is divided for commercial purposes into several different grades, such as Minnesota, Red Lake, Soudan and Vermilion. These were the first mines opened in Minnesota, and have been fully described in the Geological Survey

Bulletin No. 6, and in other publications. The method of mining is described on page 589 of this chapter.

Mesabi Range mines. With only six full seasons' operation to its credit, this wonderful range has already produced about 17,000,000 gross tons of soft hematite. Its discovery and development have affected the price of iron and steel throughout the entire world, and upon its store of iron are dependent many of the large furnaces of unprecedented cost and capacity now in process of erection or recently completed throughout the eastern and central portions of the country.

As shown by the tables of analyses, the grade of the Mesabi ore averages higher than that of any of the other ranges; but, as seen in the table of prices, it sells for a lower price in the market, owing to the lower cost of production, and to mechanical difficulties in using it alone in the furnace.

The mines of the Mesabi also occur in groups. The easternmost of these groups is at Biwabik. Here are situated the Hale, Cincinnati, Biwabik, Canton and Rouchleau mines. Of these the Hale and Biwabik are operated in open pits, and the others under ground. The Biwabik is one of the four largest open pit mines on the Mesabi, and is worked by steam shovels.

Between Biwabik and Eveleth are several mines, among them being the McKinley, Sparta and Genoa, all worked as underground propositions. At Eveleth are the Adams, Vega and Fayal, the last being one of the largest and best developed mines on the range. It is worked both in open pit and underground.

North of Eveleth occur the Auburn, Minnewas, Ohio, Norman, Franklin, Oliver or Missabe Mountain, Commodore and Sauntry and several other mines and undeveloped deposits near Virginia. The Oliver, with the Lone Jack and Ohio, is one of the large open pit steam shovel mines, and has made a great record.

The Mountain Iron group is chiefly under one management, that of the Carnegie interests, although it was extensively and admirably developed by the Lake Superior Consolidated Company before it was leased to the present operators. This is the largest open pit mine on the range, as at present developed.

Some smaller deposits occur between Mountain Iron and Hibbing; but, with the exception of Pillsbury, they have not yet appeared in the list of large producers. At and near Hibbing are the Mahoning, a very large open pit mine, the Hull, Rust and Burt, operated by the Consolidated company, the Penobscot, Sellers and several other minor properties.

West of Hibbing there have been some small and one or two large deposits developed, but none of them are as yet producing. On the western Mesabi, as on the Vermilion, there will yet be opened other mines, perhaps as good as those now being worked. The promise is not so good, however, for the discovery of merchantable ore on the eastern portion of the two ranges. Detailed accounts of many of these mines are to be found in the papers of the present writer, of F. W. Denton, and others, as listed in the bibliography appended hereto.

LAKE SUPERIOR IRON ORE SHIPMENTS (GROSS TONS) FOR 1898 AND THE PREVIOUS FORTY-THREE YEARS.*

NAME OF MINE.	Prior to 1882.	1882	1883	1884	1885	1886	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	TOTALS
Marquette range.																			
American (Sterling)	5,499	8,006	3,618	2,916			1,483	13,699	20,032	21,000	21,604	15,076							112,933
Ames													1,103	5,195					6,298
Barnum (b)	488,311	41,778	62,752	69,408	47,458	52,975	16,123	10,211	12,835										801,851
Bay State	14,770	1,236	631																16,637
Bessie											847								847
Beauford		5,532	18,976	18,360	17,166	17,354	12,829												90,217
Blue													13,809	32,171	44,140		2,519		92,639
Boston	21,302	18,245	20,190	2,218												587			62,542
Buffalo (a)						10,860	24,686	30,801	50,919	100,464									217,730
Braastad { Mitchell	75,713	33,396				7,017	16,419	4,091											136,636
Braastad { Winthrop	256,300	23,005	50,143	73,144	53,913	58,743	74,067	86,789	155,341										831,445
Cambria	55,704	64,545	47,508	59,742	50,796	58,784	41,130	57,861	72,780	80,359	34,662	41,549	30,445	47,218	41,656	95,086	110,648	102,623	1,093,096
Champion	975,907	159,009	104,960	210,180	173,915	137,593	146,330	174,680	215,098	223,442	133,413	109,979	61,648	42,788	100,398	113,375	141,728	163,190	3,387,633
Chicago	8,895		117																9,012
Cleveland Cliffs Iron company	2,425,079	206,120	218,219	225,674	218,757	203,664	207,441	184,316	274,048	331,713	221,788	310,907	218,105	143,706	221,153	513,119	718,108	869,482	7,711,699
Columbia (Kolm'n)	82,033	12,066	714																94,813
Curry									16,671										16,671
Detroit		5,402	12,314	3,809	19,125	39,400	26,099	18,500	10,112	6,080									140,841
Dexter			4,878	16,202	750			1,821	3,895	9,136	5,448	13,000	7,833	21,740	13,752	18,903	1,154		118,512
Dey				2,709															2,709
East Champion	64,264	4,002	5,039						2,697										76,002
East New York								13,694	29,739	36,431	50,293	35,175	911						166,243
Edison									893										983
Erie		2,731	5,405																8,136
Etna			1,091																1,091
Fitch										16,550	15,093				174				31,817
Foster (b)	108,949	11,648	10,029	9,675	9,643					21,949									171,893
Gibson					1,515	12,142	2,700												16,357
Goodrich	39,756	9,998																	49,754
Grand Rapids (Davis)							1,200	11,611	20,058	26,426	9,362	22,823	352	12,073	6,764	67			110,736
Hartford									566			5,678	6,513			1,532			14,289
Hortense (North Champion)							886	5,685	7,757	16,246									30,574
Humboldt	495,496	43,463	31,866	23,763	11,766	20,207	19,873	11,655	15,866	23,259	19,879	4,571				2,297			723,961
Iron Cliffs (k)							87,346	78,520	134,616	188,776	278,270	289,395	130,812	253,760	259,042				1,700,537
Imperial										38,460	18,552	7,194							64,206
Iron Mountain							393												393
Jackson	2,195,162	96,830	71,278	83,251	68,657	89,370	109,906	101,909	128,891	124,682	92,979	92,567	51,009	32,298	42,186	80,710	79,102	55.012	3,595,799
Lake Superior	2,696,456	296,509	200,799	204,796	226,040	267,622	302,909	240,225	288,784	318,321	308,831	366,715	329,610	344,758	342,439	459,576	376,761	686,563	8,257,714
Lillie	82,053	27,494	4,614	2,683	708	3,957	23,041	32,692	33,916	31,812	19,551	29,005	68,861	78,388	54,285	107,532	112,781	211,023	924,396
Lucy (McComber)	252,345	40,406	14,676				12,139	22,276	32,982	43,483	27,683	26,326	21,964				10,033	11,846	516,159
Manganese			397	1,484	3,111	1,367													6,359
Marquette (c)						5,229	20,441	7,060	70,128	23,692	16,802	9,555							152,907
Mesabi's Friend															5,503	10,540			16,043
Michigamme	443,247	43,712	42,533	25,935	12,373	48,790	58,726	36,448	56,999	80,777	23,169	1,894	935	1,610	3,214				880,362
Milwaukee	45,718	40,891	805	25,991	38,465	46,693	50,490	48,908	52,727	24,763									375,451
National	91,685	23,366	21,178	13,987															150,216
Negaunee							5,259	45,304	78,318	76,488	64,218	85,846	69,732	132,581	90,682	175,394	182,169	191,330	1,197,321
Negaunee Consolidated Works		1,177	10,394	43		1,094													12,708
New York (York)	975,001	56,806	1,517	1,677			5,128		12,844	2,422		11,220	25,000	21,487					1,113,102
New York Hematite	35,482	2,105																	37,587
North Republic								289											289
Northwest												1,687							1,687
Norwood							2,200	3,553											5,753
Nonpareil (St. Lawrence)		9,998	11,961				1,436												23,395
Ogden																	986		986
Palmer																1,041			1,041
Pascoe		18,880		12,605	18,249	10,072													59,806
Pendill	34,094	9,987	318	1,594															45,993
Phenix (Dalliba)	10,986	44,836	1,687				1,605												59,114

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LAKE SUPERIOR IRON ORE SHIPMENTS (GROSS TONS) FOR 1898 AND THE PREVIOUS FORTY-THREE YEARS.*—*Continued.*

NAME OF MINE	Prior to 1882	1882	1883	1884	1885	1886	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	TOTALS.
Pioneer						5,140	1,203	9,066											15,409
Pittsburg & L. Angel'e	525,697	14,326	27,259	86,922	111,051	131,731	191,120	223,600	229,070	261,681	241,605	287,517	351,973	355,453	313,555	342,251	489,685	460,333	4,644,829
Platt												2,676	5,448	41,226	13,198	11,296			73,844
Primrose																6,040			6,040
Prince of Wales (a)										32,415									32,415
Princeton (Sw'nz'y)	94,741	31,498	13,730	3,557		8,328	2,842				7,301	29,403	19,096		6,593			25,247	242,336
Quartz									491										491
Queen (a)								5.527	66,122	109,217									180,866
Queen Iron Manufacturing Co. (f)											479,509	379,719	106,864	220,298	160,817	323,057	239,774	61,022	1,971,060
Republic	1,427,399	235,109	152,565	277,757	250,835	241,161	220,324	235,062	287,390	220,065	191,127	167,991	64,195	105,719	174,027	127,360	124,342	140,312	4,643,040
Republic Reduction company							87	21,050	22,122	3,915									47,174
Richards							1,374										6,887		8,261
Richmond																1,088	4,630	24,464	30,182
Riverside								5,622	3,712		6,783		43						16,160
Rolling Mill	221,814	163	1,528	1,820	3,437	4,403	1,058	402									3,975		238,600
Saginaw	420,774	16,276	9,108	946							4,320								451,424
Salisbury (b)	237,843	42,243	17,028	26,629	29,503	51,667	48,304	74,947	72,449	85,798									686,411
Sam Mitchell						8,823	8,411	546											17,780
Samson (Argyle)	228,091	12,421	15,700	1,334		1,133		4,512	2,796	1,218		600							267,805
Schadt															1,261				1,261
Section 12	18,600	3,287																	21,887
South Buffalo (a)							4,964	24,706	69,359	146,383									245,412
Spurr	145,552	8,873	9,067			752													164,244
Star West (Wheat)	16,414	9,554	6,625	6,824	9,200	15,867	17,538	4,987	7,997	15,141	4,412			5,550	51,207	9,658	942		181,946
Taylor	11,669	15,146	6,155																32,970
Titan		1,778	13,128	19,411	23,340	13,865	16,003	2,846											90,371
Volunteer	263,129	41,456	19,414	11,748	5,679	24,034	47,486	56,321	60,156	141,524	92,699	127,130	69,561	26,946	32,672	53,216	1,617		1,074,788
Webster		4,443		934		6,229	2,054		448										14,108
West Republic	7,354	27,865	30,734	19,623	12,700	10,558	12,872	9,861	1,510										133,077
Wetmore		1,777	2,777	4,585	5,887	10,756	3,335	2,074	19,679										50,870
Wheeling				4,098	6,383		74												10,555
Winthrop										109,576	122,042	191,658	180,071	134,365	119,120	150,496	106,894	122,592	1,236,814
Total	15,599,314	1 829,394	1 305,425	1 558,034	1 430,422	1 627,380	1 851,634	1 923,727	2 642,813	2 993,664	2 512,242	2 666,856	1 835,893	2 059,330	2 097,838	2 604,221	2 715,035	3 125,039	52,378,261
Mesabi range.																			
Adams															59,141	234,562	170,738	390,860	855,301
Aetna (Lowmore)													1,645			17,723			19,368
Auburn														108,210	376,970	131,478	175,263	235,630	1,027,551
Biwabik													151,500	90,048	247,069	242,565	427,464	383,180	1,541,826
Canton													24,416	213,853	359,020	16,261			613,550
Cincinnati													26,372		17,187	57,324	32,912		133,795
Cloquet (Vega)														5,628	47,700	96,280	12,215		161,823
Commodore													65,137	7,213		22,063	60,798	80,494	235,705
Day																		18,651	18,651
Duluth													37,626					112,155	149,781
Elba																		564	564
Fayal															136,601	248,645	642,939	575,933	1,604,118
Franklin													46,617	223,399	286,423	231,086	30,128	200,400	1,018,053
Genoa																17,136	309,514	279,677	606,327
Hale													3,616	24,167	31,004	70,006	13,728		142,521
Lake Superior															58,123	67,659	259,912	135,404	521,098
Mahoning															117,884	167,245	519,892	520,751	1,325,772
Minnewas													13,858	2,140					15,998
Mountain Iron (& Rath)												4,245	119,818	573,440	371,274	142,021	773,538	650,955	2,635,291
Norman														38,999	93,392	77,523	101,077	110,141	421,132
Ohio															28,943	69,925	47,350	101,697	247,825
Oliver (i)													123,015	505,955	500,377	808,291	601,072	349,100	2,887,810
Penobscot																	11,933	29,652	41,585
Pillsbury																		99,691	99,691
Roberts																	18,614		18,614
Sellers															47,433	153,037		112,765	313,235

Lake Superior iron ore shipments.]

Sparta																	66,722	226,156	292,878
Williams (North Cincinnati)															3,046	11,249			14,295
Total												4,245	613,620	1 793,052	2 781,587	2 882,079	4 275,809	4 613,766	16,964,158
Miscellaneous				1,879	441														2,320
Menominee range.																			
Antoine															27,931	110,821	98,847	104,510	342,102
Appleton												4,377	5,618		2,107				12,109
Aragon									1,745	46,609	96,829	167,948	127,901	138,209	183,296	95,809	149,594	295,821	1,303,761
Armenia									50,275	26 649					2,045				78,969
Beta						1,585	1,226				1,400								4,211
Breen	17,430																		17,430
Brier Hill		10,593	4,388																14,981
Calumet		5,847	29,239	3,627															38,713
Chapin	169,077	247,506	265,830	290,972	157,455	198,871	336,128	290,871	518,990	742,843	488,749	660,052	489,134	235,895	618,589	420,318	643,402	724,768	7,499,450
Claire												57,352	9,612						66,964
Columbia (h)		15,948	4,334	6,774		14,282	2,377	10,936	11,385	60,133	70,770	57,682	22,426	10,300	70,867	87,202	24,623	14,199	484,238
Commonwealth	107,053	115,862	21,493	34,622	42,947	51,189	56,609	61,818	108,515	116,786	134,982	249,113	151,291	174,921	208,880	93,707	98,283	250,687	2,078,758
Cornell	42,672					4,566	2,064												49,302
Crystal Falls		1,341								3,974					13,037	44,526	95,210	128,233	286,321
Cundy																3,395	41,942	76,817	122,214
Curry (g)	52,188	13,374	3,676	10,079	4,897			5,376	28,722	72,162	100,681	125,773							416,928
Cyclops (g)	79,198	18,287	22,675	24,099	49,897	37,189	14,297	14,693	6,101	7,361	10,599	1,697							286,093
Delphic			3,410	508	9,880	17,648	2,272									52			33,770
Dober																		5,009	5,009
Dunn							24,677	118,096	151,828	156,963	162,721	133,666	58,590	24,538	90,885	47,081	31,062	49,381	1,049,488
Emmett	66,655																		66,655
Fairbank		8,045	455																8,500
Florence	114,644	160,155	40,232			8,210	79,399	142,585	196,269	218,570	48,806	48,246	9,634	2,726	22,820	35,136	37,594	93,663	1,258,689
Great Western		587	22,825	20,710		22,267	23,239	21,860	38,454	72,546	62,464	87,487	661			14,643		33,851	421,594
Groveland											1,049								1,049
Half and Half									5,961	1,496	67								7,524
Hamilton						872	600	8,801	8,347	17,072	58,197	2,183							96,072
Hemlock											35,531	65,459	11,323		949	94,645	96,032	69,865	373,804
Hersel										955									955
Hiawatha													1,683		1,201				2,884
Hollister										2,020	1,057	1,021							4,098
Hope												15,543	2,275						17,818
Indiana		4,280	4,362	636	2,739	5,854													17,871
Iron River		29,115	100,369	52,584	55,693	78,591	83,018	110,000	179,238	155,458	59,345	1,176							904,587
Keel Ridge	31,007	23,425	5,033									5,997	3,298		19,441				88,201
Lee Peck (d)												2,844							2,844
Lincoln											1,813	26,019	8,757						36,589
Loretto													8,131	55,983	53,160	34,334	54,104	68,447	274,159
Ludington	12,190	52,152	102,632	101,165	124,194	74,454	101,653	61,883	116,297	97,355	141,303	15,777	109	354					1,001,518
Manganate										6,844									6,844
Mansfield										18,303	49,836	69,259	69,558				37,182	60,739	304,877
Mastodon		3,477	18,577	18,187	11,737	41,640	48,792	51,463	63,511	66,526	45,370	9,150	23,485		23,733	60			425,708
Metropolitan		23,854	36,643	27,577		6,393	9,070	3,490											107,027
Michigan Explo. company													505	77	1,071		216		1,869
Millie (Hewitt)	4,352	9,500	7,516	7,927	4,627	5,517	1,163	11,124	12,274	39,232	5,889	6,780		13,062	10,924	21,815	10,374	17,430	189,506
Monitor (Lamont)									12,348	31,139	26,226	42,819	13,777	2,600					128,909
Nanaimo		2,480	29,221	37,620		5,400	30,460	5,744		3,441	13,200								127,566
Northwestern			7,202	10,004															17,206
Norway (g)	416,037	165,547	114,836	71,710	67,741	93,878	95,726	87,260	68,044	61,717	4,089	44,767							1,291,352
Paint River		6,515	5,973	11,652	2,373	13,933	10,240	12,506	32,700	62,654	45,435	18,390							222,371
Penn Iron Mining Co.													280,450	175,274	290,622	179,917	237,886	223,713	1,387,862
Perkins	123,067	73,648	76,514	38,120	18,020	12,852	10,834	16,684	12,354	11,971					2,161				397,225
Perry			3,138																3,138
Pewabic										26,991	64,507	115,273	165,745	304,010	262,551	273,587	279,855	305,072	1,797,591
Quinnesec	164,026	44,240	21,676	16,995	14,110	13,442	6,585	2,249							761				284,084
Selden						790	1,302												2,092
Sheridan									1,102	595	7,137	45,745	2,234		16,754	3,419	146		77,132
South Mastodon								2,722	4,005	1,476									8,203
Stephenson	34,743					1,018	3,589												39,350
Sturgeon River							6,829	7,800	4,775										18,404
Vulcan (g)	272,617	94,042	79,874	101,722	124,125	143,930	205,036	129,541	153,900	104,996	78,967	179,904							1,668,654

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LAKE SUPERIOR IRON ORE SHIPMENTS (GROSS TONS) FOR 1898 AND THE PREVIOUS FORTY-THREE YEARS.*—*Continued.*

NAME OF MINE.	Prior to 1882	1882	1883	1884	1885	1886	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	TOTALS
Walpole							1,740	900	9,614	2,940	3,895								19,089
Youngstown		6,198	15,292	8,344		25,635	34,418	12,699		44,460	3,705				13		661		151,425
Total	1,706,9561	136,0181	047,415	895,634	690,435	880,006	1 193,343	1 191,101	1 796,754	2 282,237	1 824,619	2 261,499	1 466,197	1 137,949	1,923,797	81 56,046	1,937,013	2,522,265	27,453,706
Vermilion range.																			
Chandler								454,612	306,220	336,002	373,969	651,655	435,930	558,050	605,024	471,545	438,365	715,919	4,947,291
Minnesota				62,124	225,484	304,396	394,252	57,341	535,318	532,000	517,570	498,353	370,303	390,463	432,760	448,707	592,196	426,040	6,187,307
Pioneer									3,144	12,012	3,079	2,651			40,054	149,073	207,103	123,183	540,299
Zenith												14,991	14,388			18,765	40,817		88,961
Total				62,124	225,484	304,396	394,252	511,953	844,682	880,014	894,618	1 167,650	820,621	948,513	1 077,838	1 088,090	1 278,481	1 265,142	11,763,858
Gogebic range.																			
Anvil							10,075	24,676	47,000	45,690	73	42,090		13,297	68,064	57,483		5,037	313,485
Ashland					6,741	74,015	175,563	174,183	257,915	435,949	267,439	231,896	66,067	83,020	126,096	91,149	111,625	123,208	2,224,866
Atlantic							1,369								70,989	60,727	50,307	38,058	221,450
Aurora					5,422	94,553	159,252	179,937	199,865	246,695	83,554	319,482	179,028	203,152	245,883	187,169	166,122	133,076	2,403,190
Bessemer						4,788	16,101												20,889
Blue Jacket							1,799												1,799
Brotherton						8,880	21,721	40,639	53,267	80,486	46,574	130,833	18,905	47,148	40,567	50,490	46,186	73,198	658,894
Cary (and Superior)									56,542	116,203	121,186	106,484	28,578	16,559	52,349	38,821	37,308	43,162	617,192
Chicago																504			504
Colby (e)				1,022	84,302	257,432	258,518	285,880	136,833	193,038	9,619	69,968	59,346	32,616		48,492	22,921	152,875	1,672,862
Comet										2,882	10,144	54,779	9,604	11,782					89,191
Davis										1,497		21,754	15,210		10,253				48,714
Eureka										23,794	13,907	10,655	31,385	18,329	26,105	4,544			128,719
Father Hennepin								28,721	76,545	63,903	15,759								184,928
Federal										21,150	6,778								27,928
First National							1,997												1,997
Germania					5,468	19,734	61,714	53,918	103,169	52,000	22,383	4,283	7,964				1,015		331,648
Imperial												8,515							8,515
Iron Belt								30,000	51,551	110,368	1,506	161,635	23,976	45,109	148,228	81,351	96,763	58,418	808,905
Iron Chief						9,950	2,249												12,199
Iron Chief No. 2						551													551
Ironton						18,424	24,762		8,635	6,247	300								58,368
Jack Pot												3,944	1,651				1,265		6,860
Kakagon						18,449	52,179	1,228											71,904
Mikado															4,788		11,397		16,185
Montreal						23,013	43,989	38,015	42,724	16,728	70,108	58,728	34,299	46,037	138,882	131,531	191,106	270,776	1,105,936
Newport						20,184	75,660	69,145	36,987	71,488	105,606	165,962	109,718	150,392	157,821	142,369	150,979	196,953	1,453,264
Nimikon						4,105	23,217	1,313											28,635
Norrie					15,419	124,844	237,254	412,196	674,394	906,728	758,573	985,216	472,062	621,608	738,480	329,068	604,281	700,990	7,581,112
Odanah						13,714	30,475	5,412	13,354	1,065		6,711	3,956	2,437					77,124
Pabst					1,103	17,979	19,906	49,976	116,376	172,060	130,226	113,245	104,510	206,074	219,960	68,984	220,496	223,891	1,664,786
Palms							1,414	9,725	35,245	50,604	32,227	102,382	2,658	37,911	46,965	114,108	207,153	175,925	816,317
Pence								26,687	574							13,185	120		40,566
Ruby (Puritan)						16,388	45,000	3,058	9,472	11,694	913								86,525
Section 33									73,370	126,063	38,576	14,681							253,590
Shores																12,196	16,102	15,691	43,989
Sparta												2,912			1,950				4,862
Sunday Lake					1,405	10,963	18,137			6,010	64,902	56,046	22,876	34,323	20,970	89,441	45,815		370,888
Superior						2,690	27,763			36,675	10,710	13,192		30,597					121,627
Tilden											28,415	233,356	135,118	209,077	418,188	250,205	276,890	287,203	1,838,452
Trimble						10,780	12,764	2,387											25,931
Tyler's Forks										10,683									10,683
Valley						1,878													1,878
Windsor									14,576	37,210	97	53,242	2,474		11,438	28,154	385		147,576
Total				1,022	119,860	753,362	1 322,878	1 437,096	2 008,394	2 847,810	1 839,574	2 971,991	1 329,385	1 809,468	2,547,976	1 799,971	2,258,236	2,498,461	25,545,484
GRAND TOTAL	17,306,270	2 965,412	2 352,840	2 518,693	2 466,642	3 565,144	4 762,107	5 063,877	7 292,643	9 003,725	7 071,053	9 072,241	6 065,716	7 748,312	10,429,037	9 934,828	12,464,574	14,024,673	134 107,787

* *Iron Trade Review* (February 2, 1899). a—Now Queen Iron Mining Co. f—Succeeds Buffalo Mining Co. b—Now Iron Cliffs. k—Under Cleveland Cliffs Iron Co. after 1895. I—Mesabi Mountain and Lone Jack. c—1893 and later in Winthrop. d—Cherry Valley ore. e—Includes Tilden up to 1891. g—1893 and later under Penn Iron Mining Co. h—Formerly Shafer, Shelden and Union.

FUTURE OF IRON MINING IN MINNESOTA.

Unlike agricultural pursuits, the mining industry is everywhere recognized as an evanescent one. Ore deposits do not grow annually, and once taken out of the ground are not and cannot be replaced. Sooner or later all mines are exhausted, and unless new ones are discovered and opened up or new industries of different character are established, the communities which thrived in the days of active mining are deserted. Their occupation gone, the miner moves to some other mining camp, the merchant moves his store, and the professional man his office to the site of new development, and in a few years, where once were cities of thousands, there may be but a few scattered ruins.

In the western portion of the United States particularly is this transitory nature of mining forced upon the attention of the traveler. Where even the greatest of mines formerly poured out their wealth by millions, and thousands of mortals gained a good livelihood, where costly structures and machinery were grouped around the buried storehouses of treasure, are now but dilapidated wrecks and ruins, mute witnesses of the brevity of prosperity where mines are worked as extensively and exhausted so rapidly as they are in this country.

What, then, of the future of northern Minnesota? Are its cities to be deserted and its busy activities to cease with the exhaustion of its mines? If so, when may that time be expected, and where will its effects be felt most early?

Comparing northern Minnesota with most western mining regions, one is immediately impressed with the fact that, but for the mines themselves, no one would have attempted to make a residence in the out-of-the-way spots and arid, inaccessible localities where many of the latter are located. In other words, there is nothing to attract people to the typical mining camp but the mines, and the hope of employment or acquisition of wealth where speculation is rife. In Minnesota the situation is vastly different. The climate is good, rainfall is plenty, the soil is productive, harvests are bountiful, the location is central, and the market for products close at hand. Already manufacturing and agricultural industries are engaging the attention of a considerable portion of the community, and every year many miners who have made a slight competence and have grown tired of underground existence, turn their faces toward some less dangerous and equally prosperous pursuit, or settle down to spend the remainder of life on a farm.

The lumbering industry which now furnishes employment to thousands of men in northern Minnesota will continue, under proper regulation and nurture, for many years to come, and as the forests are cleared off farms will multiply.

Life of present mines. Although the present rate of production of iron ore is enormous and increasing rapidly, yet it will be many years before the mines of

Minnesota cease to furnish the best and cheapest iron ore ever mined in large quantity.

Although there is but one Mesabi range, and but few productive spots on the Vermilion range, it cannot yet be supposed that all the ore deposits have been discovered. Whole townships have yet to be prospected, and localities where the presence of ore is as yet unsuspected will probably turn out to contain as large mines as have thus far been discovered.

And even with the present rate of consumption there is, without doubt, enough ore in the mines now developed to supply all demands for more than a generation. In no mining region in this country is it so easy to thoroughly and completely explore the ore deposits, and determine closely the tonnage in any given deposit. There is thus more ore (not all merchantable at present prices, to be sure) in sight on the Mesabi range alone than has been produced from all the mines of the Lake Superior region during the past half century. In this fact, surely, there ought to be consolation. Industries may be inaugurated and capital confidently invested in the expectation that there will be no sudden cessation of this mining industry. Explorations and developments are here amply sufficient to guarantee many years of prosperous existence to these mines.

State ownership and royalties. Besides an interest of a general nature in the development and perpetuation of the iron ore industry within its borders, the State of Minnesota is directly concerned as the fee owner of property on which iron mines are located. The Missabe Mountain, operated under lease by the Oliver Mining company, and the Minnewas, operated by the Lake Superior Consolidated Iron Mines, are the best known of these state mines. There are, however, a couple of smaller deposits on lands owned by the State at points farther west on the Mesabi. As yet there are no mines located on the State's lands on the Vermilion range.

It is needless to say that these are valuable properties, and should be carefully looked after by the State's authorities. Some of the best lands have already been lost to the State, and much ore and timber are said to have been removed without the rendition of any adequate compensation to the State treasury, and all for the lack of some honest official thoroughly familiar with the region and the industry, with authority to look after the interests of the State in the same way that the representatives of private fee-owners look after the interests of their employers.

Frequent attempts have been made to secure a reduction of royalty on ore mined on the State's lands. Having found it an easy matter to procure such legislation as they desire, or to defeat any legislation proposed for the purpose of securing mine inspection or regulation, the mining interests have sought to reduce royalties on State ore. This royalty, which amounts to 25 cents per gross ton, is not excessive

and is less than the royalty paid to private fee owners in many instances. There will always be occasional periods of slack demand for iron ore, when it would seem as though more ore might be mined from these mines if the royalty is reduced; but the amount of ore owned by the State is limited, and it will all be wanted in the not far distant future, even were the royalty higher than it now is. It is a mere matter of business. The miner will always get his ore as cheaply as possible; while on the other hand, the fee owner will always get as much as he can for his ore. When therefore it is proposed by any one to reduce the State's royalty, that man may reasonably be looked upon as an agent or representative of the lessee, and should be treated accordingly. When private fee owners are receiving 35, 40 and even 50 cents per ton for ore that comes from underground mines, there is no reason why the State should receive less than 25 cents for ore that can be mined much more cheaply, and is selling at as high a price in the market.

IRON AND STEEL MANUFACTURE AT HOME.

"Show me the country which leads in the production of iron and steel, and I will show you the leader in wealth, civilization and influence," was said by some political sage. That it expresses a truth will be admitted on every hand. Until recently England has led the world in the production of iron and steel, and has been conceded to be the most powerful nation. Within the past decade the United States has taken the palm from Great Britain, and is already admitted to be in the foremost place among the nations in all that constitutes national greatness.

To a certain extent the same rule applies to communities and localities within a country. Pennsylvania and Ohio are rich, populous and influential largely because of their great iron and steel industries. Minnesota contributes in no small degree to the wealth and prosperity of these two States by sending to them the products of its iron mines for manufacture into finished articles of commerce. It becomes thus a question for serious investigation to ascertain whether iron and steel plants and manufacturing industries to utilize their output cannot be established at or near the mines, or at least within the borders of the State.

COMPARATIVE COSTS HERE AND ELSEWHERE.

From a report "Upon the manufacture of iron and steel at Marquette, Michigan, by Mr. John Birkinbine," and from some articles prepared by Mr. D. E. Woodbridge for the Minneapolis Journal, based very largely on the former article, but altered somewhat so as to apply to this state, the following extracts are taken:

"*What Minnesota pig iron would cost.* It will be easily demonstrated that Minnnesota can produce a ton of pig iron from home ores by assembling raw materials and with existing facilities at less than the cost of producing similar iron at any of the nation's great centres, Chicago, lake Erie or Pittsburg. It is easy to show, also, why the manufacture of iron here cannot now, nor perhaps for many years, be entered upon on a successful

scale under present conditions. The reason for the lower cost of manufacture is, in brief, that the great bulk of present and prospective lake traffic is eastward, freights from lake Superior to the east are higher than those in the contrary direction, and that more ore than fuel is required to produce a ton of pig iron. Both these conditions will grow more and more pronounced as time goes on.

"To introduce conclusive comparisons it will be unnecessary to make detailed estimates of the cost of producing pig iron. These estimates are mainly of temporary value, and all items except transportation and market will in every case be practically the same, except so far as may hereafter be noted. The comparison may be confined to the cost of assembling the raw materials for the ton of iron, on the one side, and the difference in labor and markets on the other.

"An examination of freight rates on the great lakes conclusively shows that for a long series of years under average conditions the freight upon lake Superior iron ores to lower lakes is twice, sometimes three times, that upon coal shipped west contemporaneously and between the same points where shipping and receiving facilities are considered equal. It is fair to assume that for the future the rate on ore east will be to that on coal west during the season of navigation, as sixty is to twenty-five, or two and three-fifths times as much.

"A blast furnace using the better grade of ore from Minnesota mines, which grade will be the one considered in this comparison, as it is the only grade valuable enough to bear the cost of transportation east, will require about 1.66 tons of ore for every ton of pig tapped out. To smelt this ore in modern furnaces under reasonably favorable conditions will require about .8 ton of coke, and this coke would require for its production 1.25 tons of coal.

"In the comparison of Minnesota-made iron and that melted on lake Erie, no account need be taken of the freight rate from the ore mines to lake Superior on the ore, nor from the coal mines to lake Erie on the coal, for both these factors are constant and equal in each case. The average freight charge for a furnace at Buffalo or Cleveland on ores from Minnesota is:

1.66 gross tons at 60 cents,	$0.90
"The freight charges on material for a furnace in Minnesota are similarly:	
1¼ gross tons of coal,	.32
Limestone, and unloading and stocking, etc., for both,	.18
Allow for extra cost of coking and loss in coal, outside limit,	.10
Total for Minnesota,	$0.60

"This shows a difference in favor of Minnesota of 30 cents a ton on the assembling of material sufficient for the production of a ton of finished pig metal, an item that, in the present days of competition and small profits, is worth striving for. As a matter of fact, the difference is more favorable to the west than here presented, for the iron ore railroads, in consideration of the fact that furnaces in the state would give them traffic all the year through, and that none of the costly dock equipments necessary for shipping to the eastern markets need be used, would make a lower freight rate for ore smelted at home than they do on ore for eastern shipment. This was demonstrated some years ago, when the Duluth & Iron Range railway made the same rate to a furnace in Duluth that it made to its shipping docks at Two Harbors, though the haul was thirty miles more. Then, too, there is an item of 10 cents for loss in coal and extra cost of coking, which is a theoretical estimate, the actual work having never shown such a loss. On the other hand there should be a saving in coking coal in the northwest, for there is a valuable residuum in the shape of tar, ammonia, gas, etc., that would be close to a market that can consume far more than the state is likely under the most favorable conditions to furnish in many years to come. This material now pays a freight from the east, where it is made in coking-works and gas plants.

"*What pig iron costs elsewhere.* The differences in favor of Minnesota under this statement are amply sufficient to cover any temporary increase in local freight charges, or difference in labor, if such exists, and demonstrate the justice of the statement that pig iron can be made more cheaply in Minnesota than in the lower lake cities.

"While the pig iron industry of the lower lakes is now very important and is destined to grow rapidly, the great centres of production in the United States today are Pittsburg and Chicago. In Pittsburg, or Allegheny county, thirty per cent of the iron made north of Birmingham, Ala., is produced. The estimated freight on material for one ton of pig iron to Chicago is:

For 1.66 tons ore at 45 cents a ton,	$0.75
0.8 ton coke at $2.50 a gross ton, all rail,	2.00
Limestone, etc.,	.05
Total for assembling materials,	$2.80

"The estimated cost of assembling materials at Pittsburg, per ton of pig iron made, is:

1.66 ton ore at 60 cents a ton, -	$0.90
Same ore, rail freight, lake Erie port to Pittsburg, at 95 cents,	1.60
Coke and limestone, by rail, at 40 cents and 22 cents per ton, -	.36
Less a credit of say 5 cents a ton on ore passing through lake Erie docks without rehandling there,	.08
Total for assembling materials, - - - -	$2.78

"To equate these figures with those for Minnesota, there should be added to the Minnesota estimates given above the cost of getting the coal or coke from mines to docks at lake Erie,

Which might be as much as	$1.30
Adding the cost of lake freights, etc., as above,	.60
Total for assembling materials,	$1.90

"All this shows a difference in favor of Minnesota of about 90 cents over Pittsburg and Chicago, and 60 cents a ton over any point on lake Erie, which has of recent years been called the 'iron coast of America.'

"*Iron's contribution to labor.* Roughly speaking, on the average, every ton of iron ore mined in this state contributes to labor in the state the sum of from 50 cents to $1.00, this including not mining alone, but all labor connected therewith, mining, transportation to docks, handling and other costs. This ore goes on to Pittsburg or Cleveland or Chicago, contributes $6.00 more to labor and becomes a steel billet. Another $2.00 and it is a rail; still another $2.00 and it is a beam of simple design. Perhaps it is made into barbed wire or nails and labor gets $4.00 to $5.00 more for every ton; perhaps it goes so far as to be watch screws, and the cost of labor involved is thousands of dollars for every ton. No wonder money is pouring into the manufacturing centres faster than they can spend it, and their farmers and tradespeople prosper. For all this, Minnesota and Michigan supply the raw material and get from 50 cents to $1.00 a ton.

"'*Lean' ores could be used.* One point not considered in these comparisons, but of importance in the same connection, is the possible use of ores for furnaces in Minnesota which cannot bear the long transportation to the east and which may be secured at much less cost than their proportionate metallic iron content would make them worth smelting. There are miles and miles of material used in grading on wagon and rail road in northern Minnesota and thousands and thousands of tons of refuse cast aside that is richer in iron than ores that are regularly smelted in the south or in many foreign countries. This is under fifty to fifty-five per cent. metallic iron and is not of a grade that can bear the costly transportation to distant furnaces, but it must be moved by the mine operator, as a waste and valueless product of his mine. Any price above cost for these ores would probably be gladly received by the miner, and the ores would bear the freight costs to furnaces in the state if the price made on them was even slightly shaded from the going values. It is believed that a profitable business might be worked up in the smelting of these lean ores, which, it must be understood, make as good an iron as the richer ores, requiring only some more fuel and more labor.

"The varieties of ores to be found in this state make an important factor in the discussion of this general question of smelting in Minnesota. Almost any desired mixture can be obtained at any time, practically within a few hours' notice. Although the region has a well-recognized reputation for its supplies of low-phosphorus ores rich in iron, there are large quantities obtainable that are not within the 'Bessemer limit' as to phosphorus, and sell very low. There are deposits, entitled to be called enormous, that are lower in iron than can be shipped long distances at a profit, as above referred to, and the State of Minnesota itself owns a considerable portion of these ores.

"If two tons of these leaner ores are smelted with one ton of coke to make a ton of pig iron, the furnaces at Buffalo or Cleveland would pay for:

Transportation on ore about,	$1.20
Those at Chicago would pay about,	.95
While those in Minnesota would pay for carriage of coke about,	.75

"As for Pittsburg, the cost of rail-haul on the ore from lake Erie is such as to make the calculation to that point unnecessary, while for Chicago there must be added to the figure of 95 cents the freight by rail on coke from the mines, which would put that point also out of the running.

"*Obstacles to home manufacture.* With these advantages in favor of the western iron-maker, added to those of a market, it may be asked with pertinence, why has not an iron industry grown up in this state already, since for sixteen years Minnesota has been recognized as a miner of high-grade ores? Experiments have been made and have failed, but have failed by reason of errors that can be avoided by every prudent manufacturer. These failures have no bearing on the question at issue. They are neither here nor there. But there are obstacles which no man who seeks for a western location for the establishment of an iron and steel plant can overlook and which will operate to retain the seats of manufacture where they now are unless radical measures are taken to overcome them.

"*The inertia of capital.* In the past few years there have grown up in the eastern centres vast aggregations of capital in the steel trade, with plants for manufacture of everything from coke and pig iron to the most finished forms of steel. It would cost millions on millions to move these plants, and their owners are doing well enough where they are. They are located in the greatest labor centres of the union, where steel workers are as common as lumbermen are in Minnesota, and where any number of men can be had at any time for any unusual job. This in itself is an important factor. The mill-owners are at home, among their competitors and neighbors, and well located for reaching the greatest markets the world affords. Why should they move? They have an idea that Minnesota is the land of the aurora borealis and the north pole, and that people further west do not use any metal, anyway. They think they are the west; in fact, Pittsburg is referred to as the 'central west' in iron-market literature. They are close to the coke supplies and it is hard to make them see that it is cheaper to take the fuel to the ore than the ore to the fuel. There is a conservatism among capitalists that is hard to move.

They fear western legislation, and, unless large inducements can be shown them, will refuse to consider changes. They realize that any plant started in the west must not only be large and modern, but it must not rest with the manufacture of pig iron alone; it must take that iron to the finished forms, and this is a complex undertaking that requires large capital and expert knowledge. While the blast furnace is, in the present state of the art, the initial metallurgical process, it is not a promising field for investment alone. There must be foundries and mills for reducing the metal of the furnace, and these, whether connected with it at one point and in one group of industries, or scattered over an entire state, must be on hand before the furnace can be successfully operated. The eastern steel-maker does not take pains to learn that in Minnesota and the northwest there are now plants that can take care of the output of a very respectable furnace, providing that furnace can furnish a metal to suit their varied requirements. It is hoped to show in this article that the market of the country tributary to Minnesota does now absorb a vast quantity of metal in various finished forms, and that millions of dollars might be saved to the State if it were manufactured here.

"Every manufacturer realizes that in a new plant, and especially in a new and comparatively untried location, he must give inducements in order to command business. He must not only sell as good goods, but better, not only give as favorable terms, but longer time, and shaded prices, or he will be unable to overcome the inertia of the buyer who has been trading elsewhere and has been satisfied. He realizes that this is far more of a factor than the ordinary man out of the business can believe. It will require considerable of an inducement, for a time, to enable him to overcome this one fact. He is not going to move for his health, nor for the friendship he has for the location that is asking him to come. If he can do well enough at home, and have none of the troubles incident to removal, erecting new plants, gathering new customers, learning a new series of credits, new freight conditions, and new climatic agencies, he will stay at home and the location that wants him may whistle till doomsday for all of him.

"He knows, too, that for a time at least any new location will demand the payment of a higher wage per ton of product than in the sections where iron workers are plenty and the trade is a main industry. This item would probably not be against the manufacturer long, for men would come in, but for a time it would be an item of considerable importance.

"*Cost of handling pig iron.* If lake Superior were open for navigation throughout the year and if pig iron were sold in cargo lots and could be handled at the small costs that accrue to iron ores, it might be found that the metal could be produced at the head of lake Superior and marketed in competition with furnaces at the eastern centres named in this discussion. But the metal must be considered as forwarded by rail tariffs throughout the year, or during the water shipping season principally in lots of less than cargoes at increased rates, and as the handling of pig iron is found to be very much more expensive than that of iron ores, therefore the market for a blast furnace plant would be confined to territory to which it is naturally tributary, influenced by interferance of established lines of traffic and advantages given to established terminals."

In a paper on "The Lake Superior Iron Mines," read before "The Institution of Civil Engineers," in London, February 14, 1899, by Messrs. Jeremiah and A. P. Head, it was frankly admitted that the cheapness and abundance of lake Superior iron ores have made it possible to produce steel in this country cheaper than in England. These gentlemen speak as follows:

"It appears that Bessemer pig iron can be produced at Pittsburg, under present conditions, for almost £1 per ton less than at Middlesbrough. This advantage is principally due to the lake Superior ore and the Pennsylvania fuel supply. It will be readily seen that by the time the pig iron has been converted into ingots, and further into finished steel, the advantage has been increased in proportion to the loss in conversion, and by reason of the lower cost of fuel required in the later processes."

After a table showing the selling price of steel rails, ship plates, billets and blooms to be from 9 shillings to £1 4s. lower in Pittsburg than in Middlesbrough, England, the Messrs. Head go on to say that—

"These figures seem to show that the present low prices of American steel are justified, if only by the cheapness of the pig iron from which it is made; and that the competition now felt in England and in neutral markets is likely to continue,

and can only be met by lower costs on the part of English producers in all available directions.

"Pittsburg has been mentioned as the principal ore-smelting point, although there are others, notably Youngstown, in Ohio. Pittsburg is 150 miles from lake Erie. As only about 1.66 tons of Bessemer ore are required to make one ton of Bessemer pig iron, and in the best practice only about sixteen hundred weight of coke, it is clearly better that the blast furnaces should be situated near the ore than near the fuel centre. This, however, involves other considerations of a somewhat complex character, such as the direction and distance of the centre of consumption. Authorities in the United States are fairly agreed that the south shore Erie ports are the best smelting and distributing centres for pig iron and steel, as well as the best receiving centres for the ore. * * *

"The authors are inclined to the view that lake Superior iron ores are likely to have a considerable and permanent effect in cheapening iron and steel, and all goods made therefrom, throughout the markets of the world; and that they will tend to encourage the production of such goods, and especially of ocean-going ships and engines at United States ports to a hitherto unprecedented extent."

No further testimony is needed as to the natural advantages which Minnesota possesses for the manufacture of her iron ores within her own borders. It is unfortunate for us that natural advantages are not always sufficient to bring about the establishment of large industries. Concentration of wealth and population has proceeded to such an extent in eastern states, and transportation and trade lines have been developed to such an extent, especially since the recent combinations of different iron and steel and other industries, that it will not be an easy matter to enlist enough financial support and commercial influence to successfully inaugurate a period of iron and steel manufacture in Minnesota. The growing importance of western markets, and the increasing wealth and independence of the western states will, we believe, eventually lead to the establishment of modern and economical plants and the upbuilding of extensive industries at the points most favored by natural characteristics. To aid in this greatly to be desired event, and to safeguard and prolong the iron industry in Minnesota should be the aim of every patriotic citizen.

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GEOLO
ITASCA COUNTY
T. 56 N.
T. 57 N.
T. 55 N.
T. 54 N.
R. 27 W.
R. 26 W.
R. 25 W.
R. 24 W.
R. 23 W.
R. 22 W.
R. 21 W.
R. 20 W.
Trout Lake
Swan Lake
Swan River
Prairie River
Pokegama Lake
Lower Falls
Upper Falls
GRAND RAPIDS
LA PRAIRIE
DULUTH MISSISSIPPI RIVER AND NORTHERN RAILWAY
Quaternary (Glacial drift)
Flat or undulating till
Terminal moraines
Cretace
Shales, clays,

GEOLOGICAL AND NATURAL HIS

OGICAL MAP OF TH

By N. H. Win

Oscar Halvo

ST. LOUIS COUN

T. 58 N. T. 59 N. T. 60 N.

R. 20 W. R. 19 W. R. 18 W. R. 17 W. R. 16 W. R. 15 W. R. 14 W.

Explana

Cabotian (Eruptive)

taceous — *lays, conglomerates*

Diabase sills *Red rock* *Gabbro* *Upper slates*

RAL HISTORY SURVEY OF MINNESOTA

THE MESABI IRON RAN

By N. H. Winchell.

Oscar Halvorsen, Draughtsman,

xplanation

Animikie (Lower Cambrian)

Upper slates | Black slates | Taconyte (iron ore) | Pokegama quartzyte | Granite | Mica schist

TA
RANGE
COUNTY
COOK CO.
T. 64 N.
T. 65 N.
ONTARIO
PORT ARTHUR, DULUTH & WESTERN RY.
GUN-FLINT-LAKE
1547
Loon Lake
North Lake
Continental Divide
South Lake
Fraser L.
L. Isabelle
R. 8 W.
R. 7 W.
R. 6 W.
R. 5 W.
R. 4 W.
R. 3 W.
R. 2 W.
Archean
Mica schist
Upper Keewatin
Pewabic quartzyte and iron ore
Lower Keewatin

GEOGRAPHICAL AND PERSONAL INDEX.

SCIENTIFIC INDEX.

ERRATA.

Page 29, third line from the bottom, for "1.43," read 1:43.
Page 67, under the figure the scale should read twelve feet to an inch.
Page 123, tenth line, for "townships," read sections.
Page 185, ninth line of small pica, for "southwest," read southeast.
Page 527, fifteenth line from the bottom, for "a matrix," read the matrix.